SCIENTIFIC AGRICULTURE

Volume 23 MAY, 1943 No. 9

THE EFFECT OF CRESTED WHEAT GRASS ON SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOIL[1]

J. J. LEHANE[2] AND W. J. STAPLE[3]

Dominion Experimental Station, Swift Current, Sask.

[Received for publication November 30, 1942]

A large scale regrassing program has been carried on during the past 6 years in the brown soil zone of Western Canada. Crested wheat grass (*Agropyron Cristatum* (L) Beauv.) has germinated and survived better than other grasses and has proved to be a relatively efficient utilizer of moisture under dry conditions. It is now the predominant cultivated grass in this area. While the regrassing program has been primarily for stabilizing areas subject to erosion, and increasing the grazing capacity of abandoned fields and overgrazed areas, the effect of the grass on the chemical and physical properties of the soil is also important and is one of the problems under investigation at this laboratory.

Experiments conducted by Bouyoucos (1) and by Coile (5) showed that incorporated organic matter tends to increase the available moisture holding capacity of the soil. The largest increases were shown by the coarser textured soils. In a survey made throughout the Prairie Provinces, Caldwell *et al.* (4) showed that cultivation reduced the organic carbon in the 0–6 layer in the brown soil zone by 13,080 pounds and the nitrogen by 765 pounds per acre. Stevenson and White (7) studied the distribution, build up, and tensile strength of roots from crested wheat grass, brome grass, and slender wheat grass. Their results showed that 88% by weight of the roots was found in the first foot of soil. The distribution for all 3 grasses in the layers 0–3″, 3–6″, 6–9″ and 9–12″ was 50, 25, 15 and 10% respectively. The weight of crested wheat grass roots was slightly higher than brome grass and considerably higher than slender wheat grass. Crested wheat grass had the largest and strongest roots and slender wheat grass the smallest and weakest.

An experiment conducted by Doughty (6) gave the carbon and nitrogen content of the crowns and roots of a number of grasses, and the rate of decomposition as measured by the production of carbon dioxide. Crested wheat grass crown and roots contained 29.4% carbon and 0.98% nitrogen and lost approximately 19.2% of carbon by the evolution of carbon dioxide in 133 days.

MATERIALS AND METHODS

Soil samples representative of the major soil types were collected from widely separated points in southwestern Saskatchewan. Composite

[1] Contribution from the Experimental Farms Service (P.F.R.A.), Dominion Department of Agriculture Ottawa, Canada.
[2] Agricultural Assistant, Soil Research Laboratory.
[3] Agricultural Scientist, Soil Research Laboratory.

samples to a depth of 6 inches were taken both from crested wheat grass sod and from a nearby cultivated soil. The samples from the latter were used as checks. The samples were air-dried, and when necessary were slightly pulverized, in order to get a homogenous mixture. Portions of the sod samples were then put in 1-gallon crocks placed in the greenhouse, and kept at favourable moisture for 5- and 10-month periods.

In order to compare the different treatments, the field capacity, wilting point moisture, apparent specific gravity, organic carbon, nitrogen, the dry aggregate structure and water-stable aggregates were determined, on the cultivated soil, the undecomposed sod, the sod decomposed for 5 months and the sod decomposed for 10 months. The mechanical analysis was determined for the cultivated, and the undecomposed sod samples. The percentage of roots and crowns were obtained on the fresh sod samples.

The following methods were used for the moisture determinations and the physical and chemical analysis.

To determine the field capacity moisture, air-dried soil was packed uniformly in cylinders 10 inches in height and sufficient water was added to wet the soil to a depth of 8 or 9 inches. After 48 hours the top $1\frac{1}{2}$ inches of soil was removed, and composite samples were taken from the next 4 inches for moisture determinations.

The permanent wilting percentage was obtained by the direct method of growing dwarf sunflowers as outlined by Work and Lewis (8). The apparent specific gravity or volume weight was determined by the uniform packing of air-dried soil in a graduate cylinder. The mechanical analysis was carried out by the Bouyoucos hydrometer method (2) after the organic matter had been oxidized with H_2O_2.

The grass roots and crowns were separated from the soil by washing through a fine mesh sieve. The sieve contents, consisting of root fibres, coarse sand and other foreign material were dried at 105° C. The fibre was separated from the dross by floatation in carbon tetrachloride. Then the fibre was redried and weighed.

The nitrogen was determined by the Kjeldahl-Gunning method, except that selenium powder was included with the salt mixture to reduce the time required for digestion. This determination does not include nitrate nitrogen. Carbon was determined by the wet oxidation method for organic carbon in soils, as outlined in Method of Analysis. A.O.A.C. 4th Edition, 1935.

The dry aggregate structure was determined by direct sieving. The water-stable aggregates were determined by the Bououcos (3) hydrometer and sieving technique modified by first wetting the soil under vacuum.

The soil types, locations, mechanical compositions and percentages of roots are presented in Table 1. The mechanical analysis was determined in order to detect any large differences due to soil variation and drifting that might exist between the sod and check samples. With the exception of soils numbers 1 and 5, all check and sod samples taken from the same location were fairly uniform in their mechanical composition. The percentage of roots and crowns varies from 0.20 to 1.13%. The sandy soils contained the highest average percentage and the clays the lowest.

TABLE 1.—DESCRIPTION OF SOILS

Soil No.	Soil type and location	Roots	Mechanical composition		
			Sand	Silt	Clay
		%	%	%	%
1	Hatton, F. S. L. No. 1 Maple Creek—				
	Check		87.2	8.1	4.7
	Crested wheat sod	0.92	76.2	14.8	9.0
2	Hatton, F. S. L. No. 2 Maple Creek—				
	Check		78.7	13.3	8.0
	Crested wheat sod	0.94	72.7	17.3	10.0
3	Hatton, F. S. L. Valjean—				
	Check		74.9	16.1	9.0
	Crested wheat sod	0.88	75.9	15.1	9.0
4	Hatton, F. S. L. Mortlach—				
	Check		59.0	27.4	13.6
	Crested wheat sod	1.13	63.1	20.9	16.0
5	Haverhill, L. Lac Pelletier—				
	Check		54.4	25.2	20.4
	Crested wheat sod	0.82	39.0	40.6	20.4
6	Haverhill, L. Gull Lake—				
	Check		37.2	46.4	16.4
	Crested wheat sod	1.04	36.6	42.0	21.4
7	Weyburn, L. Scott—				
	Check		39.4	41.2	19.4
	Crested wheat sod	0.56	38.4	41.2	20.4
8	Haverhill, C. L. Swift Current—				
	Check		29.8	35.0	35.2
	Crested wheat sod	0.20	27.0	31.4	41.6
9	Fox Valley, Si. C. L. Gravelbourg—				
	Check		21.6	46.8	31.6
	Crested wheat sod	0.95	20.4	49.4	30.2
10	Sceptre, C. Shackleton—				
	Check		19.4	38.8	41.8
	Crested wheat sod	0.57	17.8	40.4	41.8
11	Sceptre, Hv. C. No. 1 Sceptre—				
	Check		11.4	18.4	70.2
	Crested wheat sod	0.43	12.0	20.6	67.4
12	Sceptre, Hv. C. No. 2. Sceptre—				
	Check		9.6	22.6	67.8
	Crested wheat sod	0.52	9.2	22.4	68.4
13	Sceptre, Hv. C. No. 3. Sceptre—				
	Check		7.0	17.0	76.0
	Crested wheat sod	0.87	9.6	16.2	74.2

EXPERIMENTAL RESULTS

The physical and chemical changes brought about by crested wheat grass are presented in Table 2. The available moisture capacity is the difference between the field capacity and wilting point moisture. This is one of the most important soil moisture measurements, as it is the moisture that is available for plant growth. The available moisture capacity expressed in pounds per cubic foot was calculated from the available moisture capacity (per cent) and the apparent specific gravity. For the sake of simplicity and economy of space, only the sum of the percentage of the separates greater than 0.83 mm. of the dry aggregate structure, and the sum of the percentages of separates greater than 0.177 mm. of the water-stable aggregates are included in this table.

In the coarse-textured soil, both the undecomposed and decomposed sod samples show a higher field capacity, a slightly higher wilting point, a higher available moisture capacity and a decreased apparent specific gravity compared with the check. The average increase in the available moisture capcity was approximately 4%, or between 2 and 3 pounds of water per cubic foot. The undecomposed sod samples averaged 11,700 pounds of organic carbon and 800 pounds of nitrogen per acre more than the check samples. The sod samples that decomposed for 5- and 10-month periods showed an average loss of 4,700 and 8,800 pounds of organic carbon, and a decrease of 140 and 330 pounds of nitrogen per acre. The decrease in nitrogen was chiefly nitrogen that was converted to the nitrate form. The dry aggregate analysis showed an increase in the percentage of separates greater than 0.83 mm. for the undecomposed and decomposed sod samples. There was no significant difference in the water-stable aggregates for any of the treatments. This indicates the weak binding properties or the instability of the aggregate in coarse-textured soils. The C/N ratio was widest for the undecomposed samples and narrowed with the decomposition of the sod.

The general picture was practically the same for the medium-textured soils except that the increases were smaller. The average increase in the available moisture holding capacity in the sod samples was between 2 and 3%, which is equivalent to approximately one pound of water per cubic foot. The average increase of organic carbon and nitrogen in the undecomposed sod sample was 8,500 and 750 pounds per acre respectively. On decomposing for 5- and 10-months, the sod samples showed an average loss of 3,500 and 4,600 pounds of organic carbon, and a decrease of 260 and 355 pounds of nitrogen. The aggregate analysis showed an increase in the percentage of large size separates for both the dry aggregates structure and the water-stable aggregates. The C/N ratio was widest for the undecomposed samples and narrowed with the decomposition of the sod.

The physical and chemical changes brought about by crested wheat grass were much less on the fine-textured soils than they were on either the coarse- or medium-textured soils. There was practically no increase in the moisture constants, and no change in the apparent specific gravity. The undecomposed sod samples showed an average gain of 1,150 pounds of organic carbon and a loss of 90 pounds of nitrogen per acre. The loss in nitrogen was probably due to soil variation. After decomposing for 5- and 10-month periods the sod samples showed a loss of 2,250 and 3,350

TABLE 2.—THE EFFECT OF CRESTED WHEAT GRASS ON SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS

Soil No.	Treatments	Field capacity	Permanent wilting point	Available moisture capacity	Apparent specific gravity	Available moisture capacity lb./cu. ft.	Carbon	Nitrogen	C/N ratio	Dry separates >0.83 mm.	Wet separates >0.177 mm.
		%	%	%			%	%		%	%
	COARSE-TEXTURED SOILS										
1	Check	10.64	3.62	7.02	1.56	8.82	.88	.091	9.7	3.5	71.4
	Sod	16.85	4.57	12.28	1.49	11.43	1.15	.124	9.3	8.6	68.9
	Sod decomposed 5 mos.	16.76	4.50	12.26	1.48	11.35	1.07	.117	9.0	6.5	69.5
	Sod decomposed 10 mos.	16.90	4.51	12.39	1.44	11.17	.97	.100	9.7	17.0	69.8
2	Check	16.60	4.73	11.87	1.44	10.70	1.50	.129	11.6	14.0	57.5
	Sod	22.25	6.23	16.02	1.35	13.52	2.50	.200	12.5	15.0	59.9
	Sod decomposed 5 mos.	22.62	5.90	16.72	1.34	14.00	2.08	.189	11.0	16.5	62.6
	Sod decomposed 10 mos.	23.00	6.68	16.32	1.30	13.25	1.59	.173	9.2	18.8	60.8
3	Check	17.67	5.51	12.16	1.44	10.96	1.36	.124	11.0	12.2	59.1
	Sod	23.25	6.62	16.63	1.36	14.15	2.50	.209	11.9	14.8	62.3
	Sod decomposed 5 mos.	23.87	6.37	17.50	1.35	14.80	2.22	.200	11.1	20.1	62.6
	Sod decomposed 10 mos.	23.20	6.20	17.00	1.35	14.35	2.03	.195	10.4	20.1	64.5
4	Check	19.12	6.96	12.16	1.29	9.86	1.47	.160	9.2	30.9	58.5
	Sod	22.37	7.09	15.28	1.23	11.75	1.46	.133	11.0	33.2	55.2
	Sod decomposed 5 mos.	21.98	6.80	15.18	1.22	11.58	1.28	.134	9.6	37.5	51.7
	Sod decomposed 10 mos.	22.67	6.90	15.77	1.22	12.10	1.21	.131	9.3	46.2	51.1
Average	Check	16.01	5.21	10.80	1.43	10.09	1.30	.126	10.4	15.1	61.6
	Sod	21.18	6.13	15.05	1.36	12.71	1.90	.167	11.2	17.9	61.6
	Sod decomposed 5 mos.	21.31	5.89	15.42	1.35	12.93	1.66	.160	10.2	22.6	61.6
	Sod decomposed 10 mos.	21.44	6.07	15.37	1.33	12.72	1.45	.150	9.7	28.0	61.5

TABLE 2.—THE EFFECT OF CRESTED WHEAT GRASS ON SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS—*Concluded*

Soil No.	Treatments	Field capacity	Permanent wilting point	Available moisture capacity	Apparent specific gravity	Available moisture capacity lb./cu. ft.	Carbon	Nitrogen	C/N ratio	Dry separates >0.83 mm.	Wet separates >0.177 mm.
	MEDIUM-TEXTURED SOILS	%	%	%			%	%		%	%
5	Check	23.80	8.09	15.71	1.32	12.95	2.46	.231	10.6	25.0	40.3
	Sod	27.35	8.96	18.39	1.27	14.58	2.70	.253	10.7	35.1	38.1
	Sod decomposed 5 mos.	28.93	8.98	19.95	1.19	14.87	2.30	.227	10.2	40.4	33.1
	Sod decomposed 10 mos.	29.39	9.68	19.71	1.16	14.32	2.23	.225	9.7	50.5	47.0
6	Check	22.36	7.98	14.38	1.31	11.80	1.76	.178	9.9	35.1	27.8
	Sod	27.33	9.45	17.88	1.18	13.20	2.95	.278	10.6	32.6	47.3
	Sod decomposed 5 mos.	27.61	9.68	17.93	1.12	12.56	2.55	.250	10.2	40.6	43.4
	Sod decomposed 10 mos.	27.16	9.61	17.55	1.10	12.10	2.41	.241	10.0	50.7	49.1
7	Check	28.70	9.87	18.83	1.19	14.00	2.97	.319	9.3	65.9	57.6
	Sod	28.90	9.32	19.58	1.20	14.70	3.01	.301	10.0	56.8	69.5
	Sod decomposed 5 mos.	29.62	9.42	20.20	1.15	14.58	2.97	.299	9.9	60.5	57.9
	Sod decomposed 10 mos.	30.26	9.74	20.52	1.14	14.60	2.96	.296	10.0	63.0	58.0
8	Check	26.31	10.68	15.63	1.19	11.63	1.40	.147	9.5	24.8	39.0
	Sod	29.08	11.82	17.26	1.14	12.30	1.48	.152	9.8	23.0	45.8
	Sod decomposed 5 mos.	29.40	12.20	17.20	1.10	11.85	1.40	.143	9.8	27.9	50.0
	Sod decomposed 10 mos.	29.22	12.58	16.64	1.09	11.35	1.32	.141	9.4	40.4	48.4
9	Check	28.06	9.93	18.13	1.15	13.05	1.90	.197	9.7	35.3	43.0
	Sod	32.80	11.41	21.39	1.02	13.60	2.93	.311	9.4	39.0	53.6
	Sod decomposed 5 mos.	32.85	11.60	21.25	1.02	13.52	2.80	.297	9.4	42.0	48.5
	Sod decomposed 10 mos.	33.42	12.27	21.15	1.02	13.48	2.72	.290	9.4	41.0	47.0
Average	Check	25.85	9.31	16.54	1.23	12.69	2.10	.214	9.8	37.2	41.5
	Sod	29.09	10.19	18.90	1.16	13.68	2.61	.259	10.1	37.3	50.9
	Sod decomposed 5 mos.	29.68	10.38	19.30	1.12	13.48	2.40	.243	9.9	42.3	46.6
	Sod decomposed 10 mos.	29.89	10.78	19.12	1.10	13.17	2.33	.238	9.7	49.1	49.9

	FINE-TEXTURED SOILS										
10	Check	34.52	13.92	20.60	1.09	14.05	2.77	.293	9.5	37.0	64.0
	Sod	33.64	14.15	19.49	1.11	13.50	2.68	.254	10.5	28.5	62.8
	Sod decomposed 5 mos.	34.48	14.21	20.27	1.07	13.55	2.48	.249	10.0	48.3	60.0
	Sod decomposed 10 mos.	34.35	14.29	20.06	1.08	13.52	2.40	.243	9.9	54.1	65.7
11	Check	41.76	19.07	22.69	1.01	14.30	1.89	.198	9.6	72.3	67.7
	Sod	40.98	20.33	20.65	1.01	13.00	1.98	.194	10.2	81.0	66.4
	Sod decomposed 5 mos.	41.66	20.80	20.86	1.00	13.05	1.84	.196	9.4	59.2	71.6
	Sod decomposed 10 mos.	41.10	21.40	19.70	1.02	12.50	1.76	.190	9.3	68.7	66.8
12	Check	40.14	19.60	20.54	.99	12.70	2.03	.203	10.0	69.1	72.3
	Sod	41.15	20.30	20.85	1.00	13.25	1.89	.167	11.3	86.2	78.4
	Sod decomposed 5 mos.	41.86	21.14	20.72	.98	12.72	1.72	.167	10.3	92.2	78.2
	Sod decomposed 10 mos.	40.86	20.68	20.18	.98	12.35	1.66	.164	10.1	76.2	81.5
13	Check	45.00	21.69	23.31	.99	14.42	1.64	.163	10.0	83.2	61.5
	Sod	46.60	21.94	24.66	1.02	15.70	2.07	.214	9.7	64.0	67.8
	Sod decomposed 5 mos.	46.13	21.85	24.28	1.04	15.76	1.95	.210	9.3	69.2	63.2
	Sod decomposed 10 mos.	46.08	21.92	24.16	1.01	15.26	1.84	.206	9.0	88.2	66.4
Average	Check	40.36	18.57	21.79	1.02	13.87	2.08	.214	9.8	65.4	66.4
	Sod	40.59	19.18	21.41	1.04	13.86	2.16	.207	10.4	64.9	68.8
	Sod decomposed 5 mos.	41.03	19.50	21.53	1.02	13.77	2.00	.206	9.8	67.0	68.2
	Sod decomposed 10 mos.	40.60	19.57	21.03	1.02	13.41	1.92	.201	9.6	71.8	70.1

pounds of organic carbon, and a decrease of 20 and 85 pounds of nitrogen per acre. The trend in the fine-textured soil was toward increased aggregation with the decomposition of the sod, but the results were so irregular between the different treatments that no significance could be attributed to them.

DISCUSSION

The sod samples of the coarse-textured soils showed by far the largest increase in the available moisture holding capacity. Calculating on the basis that the top 6 inches of soil contained 66% of the total root weight, and assuming that the remaining 34% of roots in the lower soil depths have an equivalent effect on the field capacity and the wilting point moisture, the available moisture capacity of the coarse-textured soils would be increased by 0.39 of an acre inch of water. This is very small when it is considered that the average available moisture retained within the root zone is between 4 and 5 inches, and the amount of water required to produce a 20 bushel crop of wheat is over 12 inches. Previous work at this laboratory has shown that there is no significant differences in evaporation from sod and the fallow surfaces. However, it is very probable that increased bacteriological activities which cause the decomposition of the sod would increase the available nutrients for plant growth. The increased moisture in the surface soil would be beneficial to germination. Field projects conducted at the sub-stations in southwestern Saskatchewan during the past 5 years have shown that crops grown on coarse-textured soils have a much higher water requirement than crops grown on either medium or fine textured soils. Any factor that would increase the colloidal content and the fertility of these soils would likely promote the efficient use of moisture by the crop.

It is a general practice in the brown soil zone of western Canada to seed crested wheat grass in stubble or weedy fields. This results in a heavy weed growth for 1 year and on occasions for 2 years after the grass is seeded. When the grass is established it is a common occurrence for drift material to blow from adjacent cultivated land on to the sod. It is-very likely that some of the increases in organic carbon, and probably most of the increases in nitrogen, are due to these causes. Also some of the increases may be due to random soil variation. However, the major portions of the organic carbon can be accounted for in the roots and crowns of the crested wheat grass. Part of the increase in nitrogen would be transported through the roots from the lower soil depths to the surface layer where the roots are concentrated. There is also the possibility that a portion of the nitrogen was fixed by soil organisms.

In the decomposed sod, the loss of organic carbon is attributed to the evolution of carbon dioxide, and the decrease in nitrogen to the conversion of part of the nitrogen to nitrates by bacterial action. Nitrate determinations made on a number of the samples show that the increase in nitrates was approximately equivalent to the loss of nitrogen.

The aggregate analysis of the undecomposed sod samples is not a true measure of the aggregation as the sod was pulverized in order to get a homogenous mixture. The unpulverized sod would undoubtedly show a

much higher percentage of the larger size separates. Considerable difficulty is encountered in selecting a representative sample from grass sod for aggregate analysis because of the binding properties of the roots. However, the increase in larger-size separates from the decomposed sample compared with the check should measure fairly accurately the effect of decomposition.

The increase in aggregation should be of definite benefit in preventing erosion, particularly by wind which is very prevalent in this area.

SUMMARY

Physical and chemical analyses show the effect of crested wheat grass on coarse-, medium- and fine-textured soils.

Decomposed and undecomposed sod samples from coarse- and medium-textured soils showed a large increase in the field capacity, a smaller increase in the wilting point moisture, and thus a net increase in the available moisture holding capacity. There were no significant increases in the fine-textured soils.

In practically all soils the sod samples had a higher percentage of organic carbon and nitrogen than did the check. The decomposed samples showed a loss of organic carbon and nitrogen compared to the undecomposed sod. Chemical analyses showed that the decrease in nitrogen was due to the conversion of nitrogen to nitrates.

The undecomposed sod samples had the widest C/N ratio. This narrowed subsequently with decomposition. The grass increased the dry aggregation of coarse-textured soils, and increased both the dry and wet aggregation of medium-textured soils.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Dr. J. L. Doughty for suggestions and criticisms during this investigation and helpful advice in the preparation of this paper.

REFERENCES

1. Bouyoucos G. J. The effect of organic matter on the water holding capacity and the wilting point of mineral soils. Soil Sci. 47 : 377-383. 1939.
2. Bouyoucos, G. J. Directions for making mechanical analysis of soils by the hydrometer method. Soil Sci. 42 : 225-229. 1936.
3. Bouyoucos, G. J. A method for making mechanical analysis of the ultimate natural structure of soils. Soil Sci. 40 : 381-385. 1935.
4. Caldwell, A. C., F A. Wyatt and J. D. Newton. The effect of cultivation and cropping on the chemical composition of some Western Canada prairie soils. Sci. Agr. 19 : 258-270. 1939.
5. Coile, T. S. Effect of incorporated organic matter on the moisture equivalent and the wilting percentage values of soil (abstract). Soil Sci. Soc. Amer., 3 : 43. 1938.
6. Doughty, J. L. The rate of decomposition of plant roots. Sci. Agric. 21 : 429-432. 1941.
7. Stevenson, T. M. and W. J. White. Root fibre production of some perennial grasses. Sci. Agric. 22 : 108-118. 1941.
8. Work, R. A. and M. R. Lewis. Moisture equivalent field capacity and permanent wilting percentage and their ratio in heavy soils. Agric. Eng. 15 : 355-362. 1934.

THE DIGESTIBILITY OF TYPICAL EASTERN CANADIAN FEEDS BY MARKET BACON HOGS[1]

E. W. CRAMPTON[2] AND F. WHITING[3]
Macdonald College (McGill University), P.Q.

[Received for publication July 11, 1942]

That the pig and ruminant differ markedly in their ability to digest certain feed stuffs has been recognized for some time. However, while there have been many hundred digestion trials reported for ruminants, the literature is decidedly meagre in data on the digestibility of feeds by swine. A few trials using hogs have been conducted at scattered points in the United States and European countries, but no previous work of this nature has been reported from Canadian stations.

In the utilization of the potential energy of a food the greatest and most variable losses occur during digestion. Hence the degree of digestibility of the organic energy-yielding nutrients is a fundamental measure of the feeding value of a feedstuff.

In the fall of 1941 a project was started, the objects of which were the determination of digestion coefficients of the "proximate principles" of some 16 feeds commonly fed to swine in Eastern Canada. Coupled with this was a search for a scheme of chemical description of the feeds which would be more closely correlated with demonstrated digestibility and energy value than the presently used standard feeding stuffs analysis. During the 1941 season the work was confined to obtaining data for a protein-mineral supplement and for No. 1 feed barley, the results of which are hereinafter reported.

METHOD OF INVESTIGATION

General Design of Tests

Inasmuch as none of the cereal grains or their by-products provide a complete ration for pigs it becomes necessary to compute their digestibility by indirect methods. The first step in this trial was to determine the digestibility of a protein-mineral supplement which is to be a constant part (15%) of all feed combinations to be studied in these investigations. The most commonly used plan for obtaining the digestibility of the supplement of a mixed ration, involves the feeding of the basal feed or mixture in one trial followed by a second in which the supplement is included. On the assumption that the same proportion of the basal feed eaten in the second test appears indigested in the feces as was found when the basal feed was fed alone, the digestibility of the supplement is calculated by difference.

Another method, proposed by Warth (4) and by Carbery (1), involves periods in which the basal feed is fed at constant levels while the supplement is, in 3 successive tests, increased in amount. The digestibility of the supplement is then calculated from the change in the digestibility of the total diets.

---

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Quebec, Canada, Journal Series No. 176.
[2] Professor of Animal Nutrition.
[3] Graduate Assistant, Department of Nutrition.
[4] This project was made possible through a special grant generously provided by the Provincial Department of Agriculture, Quebec.

From the data obtained in the Warth-Carbery graphical method, the digestibility of supplement and of basal feed may also be calculated as the partial regression of the digestibility of the total diet on the basal feed and on the supplement consumed.

It was desired to employ all 3 of these methods, and accordingly trials with barley unsupplemented as well as with 3 levels of the supplement were carried out.

The supplement was composed of 25 parts of meat meal, 40 parts of linseed oil meal, 15 parts of fish meal, 10 parts of bone char, 5 parts of ground limestone and 5 parts of salt. The basal feed used was No. 1 feed barley weighing 49 lb. per bushel.

The percentage composition of the supplement and of the barley was as follows:—

	Moisture	Crude protein	Ether extract	Crude fibre	Nitrogen-free extract	Ash
Supplement	8.0	34.8	4.9	5.1	18.5	28.7
Barley	12.0	13.0	1.8	5.1	65.5	2.7

The supplement was fed at levels of 10 lb., 20 lb., and 40 lb., per 100 lb. of barley (air dry weight) with the barley intake held constant in all periods.

Animal Management

Four male Yorkshire pigs of similar age and breeding, weighing an average of 97 lb. at the beginning of the first test, were used in each of the 4 periods.

The digestibility crates employed were designed at Macdonald College and are a modification of those used at the Central Experimental Farm, Ottawa. The floors of our crates are made of boiler plate metal with a depressed 1 × 2 inch diamond design on the upper surface. This is much more comfortable on the pig's feet and prevents slippage. A half-inch hole drilled through each diamond depression permits urine to drain through to a funnel shaped floor from where it is directed to a container. Another modification does away with the need of a harness on the pig with an apron attached to direct the feces into a container. Instead a metal chute is directly behind the pig, so adjusted that voided feces fall on the chute and slide to a collection pan below. The crates are adjustable on one side for width and on both ends for length so as to accommodate the size of pig used. They are adjusted so that the amount of space given to the pig is just sufficient to allow it to stand and lie comfortably but insufficient to allow it to turn around in the crate, or to move ahead enough to permit feces to fall on the floor. The ration is fed in an adjustable trough at the front of the crate. These pens have proven very satisfactory. The pigs were in them for 10 weeks during the trials, being taken out only for weighing every 2 weeks. All animals ate well, gaining about 1.25 lbs. per day during the period.

Feeding was done twice daily at 8.00 A.M. and 5.00 P.M. The meal was moistened with 3 times its weight of water and fed as a slop. No other feed or water was allowed. Any material refused or wasted at one feeding was incorporated with the next feeding.

Collection periods were of 10 days duration preceded by 5-day preliminary periods. Feed intake was kept constant throughout both periods. A "marker" (ferric oxide) was mixed in the first feed of and in the first feed after the collection period and a record kept of the amount of feces collected between the appearance of the markers for comparison with the straight 10-day collection.

Feces were collected once daily at approximately 9.30 A.M., weighed, thoroughly mixed and two 100 gm. samples taken for chemical analysis.

RESULTS

There was no significant difference between the amount of feces collected in the straight 10-day and in the "marker to marker" collections, as seen in Table I.

TABLE 1.—TOTAL DRY WEIGHT OF FECES COLLECTED IN TEN-DAY AND IN "MARKER TO MARKER" COLLECTIONS

	Av. dry weight of feces per pig (lb.)				
	Period 1	Period 2	Period 3	Period 4	Total
10-day collection	7.8	9.9	12.1	14.2	44.0
Marker collection	7.8	10.0	12.2	13.8	43.8

The fact that the use of markers is as dependable as the 10-day collection would suggest that if markers are used the preliminary period may be shortened, and also that feed intake need not necessarily be kept constant throughout the test period. (Digestibility coefficients reported herein are from marker to marker collections).

Table 2 shows the average digestibility coefficients of the four rations together with their standard errors. The standard deviations indicate that the variability from pig to pig in ability to digest the various fractions of the feed was quite small except for ether extract. Also worthy of note is the decline in the digestibility of the rations with increasing amounts of supplement other than for the crude fibre and ether extract fractions. The case of the ether extract is probably explained partly on the basis of a higher digestibility of the animal fats and in part because of a larger fat content of the supplement.

The drop in digestibility of the feed fractions of importance as sources of energy obviously does not correlate with the steady increase in rate of gain with increasing supplement. Nor does correction of gain for increasing feed or calculated total digestible nutrients intake give ratios which follow the trend of digestibility (see Table 3).

TABLE 2.—AVERAGE PER CENT DIGESTIBILITY OF THE FOUR RATIONS FED

Period	Ration	Av. wt. at start of test	Av. daily gain during test	Digestibility					
				Dry matter	Organic matter	Protein	Crude fibre	Ether extract	N-free extract
		lb.	lb.	%	%	%	%	%	%
1	Barley	98	.77	78 ± 0.4	79 ± 1.0	79 ± 2.3	20 ± 1.9	2 ± 2.1	86 ± 0.4
2	Barley 100 + Supplement 10	114	1.14	74 ± 1.4	75 ± 1.4	75 ± 2.2	18 ± 0.6	25 ± 2.5	82 ± 1.4
3	Barley 100 + Supplement 20	133	1.24	71 ± 1.4	74 ± 1.6	75 ± 2.8	18 ± 1.0	45 ± 7.6	79 ± 1.1
4	Barley 100 + Supplement 30	152	1.49	69 ± 1.2	72 ± 1.4	74 ± 1.8	21 ± 0.8	56 ± 4.4	77 ± 1.4

TABLE 3.—GAINS IN LIVE WEIGHT OF PIGS, THEIR FEED INTAKE, THE PERCENTAGE DIGESTIBILITY OF DRY MATTER OF RATIONS, AND THE RATIOS OF GAINS TO FEED AND TO TOTAL NUTRIENTS EATEN

Period	Av. daily gain	Av. daily feed eaten	Gain × 100 / Feed	Digestibility of dry matter or ration	Calculated daily total digestible (T.D.N.) consumed	Gain × 100 / T.D.N.
				%		
1	.77	3.46	22	78	2.35	33
2	1.14	3.80	30	74	2.47	41
3	1.24	4.14	30	71	2.58	48
4	1.49	4.51	33	69	2.72	55

This means that the increasing quantities of feed eaten daily were enough to offset the decline in digestibility so that the total digestible nutrient intake actually did increase and hence permitted live weight gains. The steady increase in the gain per unit of feed and of total digestible nutrients eaten is a reflection of the increased efficiency of the barley as it is increasingly fortified with proteins and minerals.

Table 4 shows a comparison of the digestibility coefficients of the supplement and of the barley by the 3 methods of calculation. In calculating digestibility coefficients by the graphical or regression method only those periods can be considered in which both the barley and supplement are fed in combination[5].

TABLE 4.—A COMPARISON OF DIGESTIBILITY COEFFICIENTS BY DIFFERENT METHODS OF CALCULATIONS

Nutrient	Digestibility of supplement			Digestibility of barley		
	By difference	Graphical*	Regression**	Directly determined*	Graphical**	Regression*
Dry matter	38	38	43	78	77	77
Organic Matter	33	50	50	79	77	77
Crude Protein	66	71	71	79	77	77
Crude Fibre	9	36	37	20	16	15
Ether Extract	117	125	125	2	−2	−2
Nitrogen-free extract	−46	−5	−6	86	84	84
Total Digestible Nutrients	35	37	38	68	66	66
Digestible Crude Protein	23	25	25	10	10	10

* From periods in which barley was fed as the entire diet.
** See Appendix.

It will be seen that in the case of the barley, both the graphic and regression methods give values agreeing satisfactorily with those directly determined though actually they are slightly lower. With the supplement however, the values obtained by difference are markedly lower than those predicted by the statistical methods from the data of the periods in which the complete ration was fed. The difference between the methods would be exaggerated in the supplement because it was but a small part of the total

[5] See Appendix.

feed. There is no way of proving which of the values are correct inasmuch as the supplement cannot be fed alone and its digestibility therefore cannot be measured directly. It may also be argued that there may be an associative effect between barley and supplement and hence that the statistical method values would be nearer those to be expected in actual feeding practice.

In any case it is evident that the supplement is not a high energy portion of the ration, the calculated total digestible nutrients being little more than half that of the basal feed.

Negative digestibility coefficients and coefficients over 100% as obtained for the nitrogen-free extract and ether extract of the supplement, respectively, are theoretically not possible, but nevertheless are not uncommon when the values must be obtained by difference. The negative value for the digestibility of the nitrogen-free extract of the supplement might be due to a depressing or associative effect of the supplement upon the digestibility of the carbohydrate fraction of the barley. The low apparent digestibility of the ether extract of the barley and the resulting high digestibility of the ether extract of the supplement is undoubtedly due in part to metabolic fat in the feces. Since ether extract makes up such a small part of the barley, a small amount of metabolic fat would greatly reduce the apparent digestibility of the ether extract of the barley. With increasing amounts of supplement fed, carrying relatively much higher fat, metabolic lipids would play a smaller part in influencing apparent digestibility of this feed fraction.

In calculating the total digestible nutrient values for the supplement, a digestibility of 100% has been used for ether extract and 0% digestibility of the nitrogen-free extract. The digestibility of these two fractions of the barley has been corrected accordingly in calculating its total digestible nutrient value.

DISCUSSION

A comparison of the results reported for this investigation with the commonly used Morrison Tables (3) which were obtained from tests with ruminants reveals that there is a marked species difference in ability to digest barley (see Table 5). The results obtained, however, agree very well with those of Fraps (2) in which swine were used.

TABLE 5.—A COMPARISON OF THE DIGESTIBILITY OF BARLEY AS OBTAINED BY VARIOUS WORKERS

	Macdonald College (swine)*	Morrison (ruminants)	Fraps (swine)
Dry matter	78	—	—
Organic matter	79	—	—
Protein	79	79	76
Crude fibre	20	56	19
Ether extract	2	80	41
Nitrogen-free extract	86	92	85
Total digestible nutrients	68	77	68
Digestible crude protein	10	10	10

* Values are those obtained by direct determination.

The digestibility of the supplement (Tables 2 and 4) is lower than might be expected. This cannot be accounted for entirely on its high mineral content (which is largely re-excreted into the feces) since the digestibility of the organic matter is also low. Thus it must be concluded that while the protein mineral supplement serves its intended purpose in bolstering up the protein and mineral content of the ration, it cannot be considered as an efficient energy yielding part of the diet.

SUMMARY

The digestibility by swine of a protein-mineral supplement and of No. 1 feed barley has been determined using 3 methods of calculation.

The 3 methods of calculating digestibility coefficients gave similar results in the case of the basal feed, barley. With the supplement, however, the values obtained by difference were markedly lower than those obtained by statistical methods from the data from periods in which the complete diet was fed.

The coefficients of digestibility and the calculated total digestible nutrients of barley are much lower than those reported for ruminants by Morrison, but agree quite closely with those reported for swine by Fraps.

The digestibility and energy value of the supplement is relatively low.

REFERENCES

1. Carbery, M., I. Chatterjee and Md. Abdul. Hye. Studies on the determination of digestibility coefficients. Indian Jour. Vet. Sc. and Animal Husb. IV, 295. 1934.
2. Fraps, G. S. Digestibility and production coefficients of hog feeds. Texas Agr. Exp. Sta. Bull. 454. 1932.
3. Morrison, F. B. Feeds and Feeding 20th Ed. Morrison Publishing Co., Ithaca, N.Y.
4. Warth, F. S. An. Report Imperial Physiological Chemist. 1928–29.

APPENDIX

The graphical calculation is made by plotting a graph in which the abscissa represents the amounts of supplement consumed and the ordinate, the total ration consumed and the amount digested on the same scale. Best fitting lines are drawn to these points, extrapolated to the ordinate erected at zero supplement and the intercepts read. Obviously the points of intersection represent the amounts of barley consumed and digested respectively when no supplement is fed (i.e. of the barley alone). The slope of the "digested" line is the digestibility of the supplement.

The graphical representation of the digestibility of crude protein is is shown as an example in Figure 1. For example in period 1, when there was 1.5 lb. protein from the supplement fed in 10 days, there was 6.9 lb. protein consumed from the total ration, and 5.2 lb. digested (figures to nearest 0.1 lb.). Corresponding values for period 2 (with 2.9 lb. protein from the supplement fed) were 8.4 lb. consumed and 6.3 lb. digested; and for period 3 (4.4 lb. protein from supplement) 9.8 lb. consumed and 7.3 lb. digested. When the points for amounts consumed and amounts digested respectively are connected by best fitting straight lines and extrapolated they intercept the ordinate at 5.50 lb. consumed and 4.23 lb. digested.

Hence the digestibility of the protein from the barley portion of the ration will be $\left(\frac{4.23}{5.50} \times 100\right) = 76.9\%$. That of the protein of the supplement may be found as the ratio of the increased amount digested from the total ration for each unit increase in protein consumed from the supplement, as $\frac{6.33 - 4.92}{3.00 - 1.00} \times 100 = 75\%$ digestibility of protein from the supplement.

Each of the individual components viz. dry matter, organic matter, crude fibre, ether extract and nitrogen-free extract has been similarly plotted and the digestibility thus calculated.

The digestibility coefficients by the regression method are obtained by solving the multiple regression equation:

$$y = ax_1 + bx_2, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

y = amount of total ration digested
x_1 = weight of barley consumed
x_2 = weight of supplement consumed
a = proportion of barley digested[6]
b = proportion of supplement digested.

From this regression equation we may construct two simultaneousequations:

$$\Sigma(x_1y) = a\Sigma(x_1)^2 + b\Sigma(x_1x_2)$$
$$\Sigma(x_2y) = a\Sigma(x_1x_2) + b\Sigma(x_2)^2,$$

the 5 coefficients of which may be obtained by direct multiplication and summation from the observed data for each of the 4 pigs in each of the 3 periods of the test. As an example the figures for protein are given below.

APPENDIX TABLE 1.—DATA FOR CALCULATION OF PARTIAL REGRESSION COEFFICIENTS a AND b FOR PROTEIN

Period	Pig No.	Amounts consumed		Total ration digested (4)
		Barley (x_1)	Supplement (x_2)	
2	1159	5.47	1.47	5.45
	1129	5.47	1.47	5.08
	1150	5.47	1.47	5.17
	1149	3.87	1.04	3.68
3	1159	5.46	2.92	6.26
	1129	5.44	2.92	5.95
	1150	5.45	2.92	6.40
	1149	3.85	2.06	4.57
4	1159	5.43	4.37	7.21
	1129	5.47	4.40	7.18
	1150	5.47	4.40	7.55
	1149	3.87	3.11	5.12

[6] In statistical terms a represents the increase in total ration digested for one unit increase in weight of barley consumed when the amount of supplement is held constant.

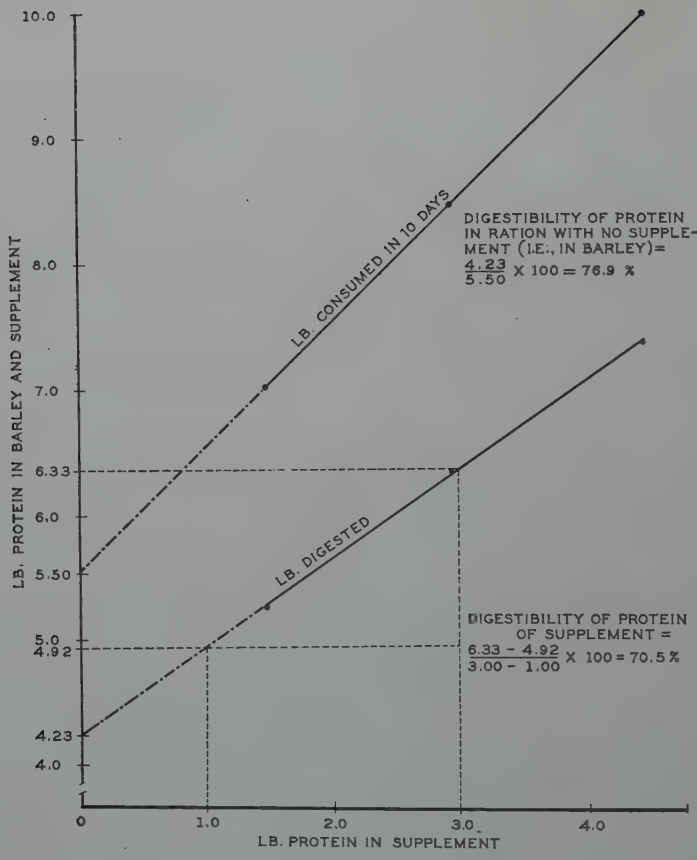


FIGURE 1. Percentage digestibility of protein (by graphical method).

$\Sigma\,(x, y) = (5.47 \times 5.45) + (5.47 \times 5.08) + (5.47 \times 5.17) + (3.87 \times 3.68)$ etc.

Substituting in the above equation we obtain,

$$358.6 = a(312.9) + b(167.7)$$
$$202.9 = a(167.7) + b(104.9),$$

whence

a, the digestibility of the barley $= 0.765$ or 76.5%
b, the digestibility of the supplement $= 0.711$ or 71.1%

THE EFFECT OF TARTAR EMETIC ON THE GREENHOUSE LEAF-TYER, PHLYCTAENIA RUBIGALIS GN.[1]

G. G. DUSTAN[2]
Dominion Entomological Laboratory, Vineland Station, Ont.

[Received for publication December 23, 1942]

The fact that tartar emetic-brown sugar sprays used for thrips control were also effective in reducing the population of the greenhouse leaf-tyer was brought to the attention of the writer by Mr. Robt. Geary of Vaughan's Seed Store, New York City. Furthermore, Burdette (1) has shown that tartar emetic combined with an invert sugar solution is an effective although rather slow-acting poison when used as a foliage spray against adults of the corn earworm, *Heliothis armigera* (Hbn.). However, up to the present time no experimental data relating to the effect of tartar emetic on the leaf-tyer have been published, as far as the writer is aware. The investigations described in this paper are presented as a progress report in the hope they will be of interest to other workers in this field.

Preliminary tests of tartar emetic-brown sugar sprays indicated that larvae of the first two instars were considerably more susceptible than older larvae and that there was some doubt as to whether the killing action was due entirely to stomach poisoning or in part to contact action.

EXPERIMENTAL PROCEDURE

In general, larvae for the tests were obtained from mass-reared cultures derived from eggs laid over a 1- to 3-day period. The larvae were transferred to the test plants by means of a camel-hair brush. As no attempt was made to determine accurately the instar of each larva, several larvae of the instar younger or older than that specified were probably present in any particular test. The results obtained with fourth and fifth instar larvae were confused by the prevalence of a disease, presumably bacterial, which sometimes resulted in a high mortality.

In all cases, except in Experiment 6, the sprays were applied with a DeVilbiss paint sprayer which delivered a fine mist.

Experiment 1

Larvae of various ages on chrysanthemum, statice, snapdragon, and mignonette were sprayed on June 20, 1941 at an air temperature of 92° F. The results in Table 1 indicated that tartar emetic with the addition of sugar was superior to tartar emetic used alone or with the addition of a spreader.

In the mortality counts, the larvae were classified as small, medium and large, roughly corresponding to first and second, third and fourth, and fifth instars respectively. The summary of these records shows clearly the greater resistance of the older larvae to both tartar emetic and lead arsenate.

[1] Contribution No. 2211, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Assistant Agricultural Scientist.

TABLE 1.—MORTALITY OF GREENHOUSE LEAF-TYER LARVAE OF VARIOUS AGES, SPRAYED JUNE 20 AND EXAMINED JUNE 25

Treatments—amounts per 80 gal.	No. larvae counted	Mortality
		%
1 Tartar emetic 2 lb. Brown sugar 4 lb.	109	61.5
2 Tartar emetic 2 lb.	66	25.9
3 Tartar emetic 2 lb. Sodium lauryl sulphate 6 oz.	40	15.0
4 Tartar emetic 2 lb. Technical mannitan monolaurate 6 oz.	76	7.8
5 Lead arsenate 4 lb. Sodium lauryl sulphate 6 oz.	49	83.7

TABLE 2.—EFFECT OF TARTAR EMETIC AND LEAD ARSENATE SPRAYS ON GREENHOUSE LEAF-TYER LARVAE OF DIFFERENT INSTARS. FROM SAME DATA AS TABLE 1.

Treatment	Percentage mortality and size of larvae		
	Small	Medium	Large
	%	%	%
1 Tartar emetic–brown sugar	96.7	63.9	25.6
2 Tartar emetic	66.6	68.8	4.5
3 Tartar emetic—sodium lauryl sulphate	100.0	33.3	3.5
4 Tartar emetic—technical mannitan monolaurate	40.0	13.3	1.3
5 Lead arsenate	100.0	83.3	58.3

Experiment 2

A number of tests were run to determine, if possible, whether tartar emetic killed by contact or stomach poisoning. In general 3 methods of treatment were employed: (1) the larvae and the plant on which they were feeding were sprayed; (2) the plant was sprayed, then dried, and unsprayed larvae transferred to it; and (3) the larvae were sprayed, then placed on unsprayed plants. In these tests the percentage mortality was based on the number of living and dead larvae recovered and not on the number originally treated.

Test A

First instar larvae were transferred to individual cucumber leaves detached from the plant and with their stems thrust into moist sand. Results are given in Table 3. Despite the fact that all larvae survived on the check it is thought that the mortality on the cucumber leaves was abnormally high owing to the unfavourable host condition.

TABLE 3.—MORTALITY OF GREENHOUSE LEAF-TYER LARVAE TREATED JULY 11 AND EXAMINED JULY 14, 1941—20 LARVAE PER LEAF

Treatment—amounts per 80 gal.	No. larvae recovered	Mortality
		%
Method 1—Larvae and foliage sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	12	100.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	20	100.0
(d) Tartar emetic 2 lb., sodium lauryl sulphate 6 oz.	16	100.0
(e) Check, water	20	0.0
Method 2—Larvae not sprayed, foliage sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	14	100.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	15	100.0
(c) Tartar emetic 2 lb.	16	62.5
Method 3—Larvae sprayed, foliage not sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	5	100.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	15	93.3
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	19	94.6

Test B

This test was similar to Test A except that the host in this case consisted of small potted snapdragon plants, and that in Method 3, the larvae instead of being sprayed, were dipped quickly in the insecticide or placed on blotting paper and flooded with the liquid by means of a pipette.

TABLE 4.—EFFECTIVENESS OF VARIOUS TARTAR EMETIC SPRAYS AGAINST GREENHOUSE LEAF-TYER LARVAE, APPLIED BY DIFFERENT METHODS; 40 LARVAE PER TEST EXCEPT WHERE OTHERWISE INDICATED

Treatment—amounts per 80 gal.	No. larvae recovered	Mortality
First and second instar larvae		%
Method 1—Leaf and larvae sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	28	100.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	27	100.0
(c) Tartar emetic 4 lb.	29	86.2
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	29	86.2
(e) Check—Water	16	0.0
(f) Check—Sodium lauryl sulphate 6 oz.	19	0.0
(g) Check—Brown sugar 4 lb.	18	0.0
Method 2—Larvae not sprayed, foliage sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	25	88.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	26	92.0
(c) Tartar emetic 4 lb.	30	80.0
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	29	44.8
Method 3—Larvae dipped, foliage not sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	40	0.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	34	0.0
(c) Tartar emetic 4 lb.	34	0.0
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	33	6.1

TABLE 4.—EFFECTIVENESS OF VARIOUS TARTAR EMETIC SPRAYS AGAINST GREENHOUSE LEAF-TYER LARVAE, APPLIED BY DIFFERENT METHODS; 40 LARVAE PER TEST EXCEPT OTHERWISE INDICATED—*Concluded*

Treatment—amounts per 80 gal.	No. larvae recovered	Mortality
Third and Fourth instar larvae		%
Method 1—Leaf and larvae sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	29	100.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	33	96.9
(c) Tartar emetic 4 lb.	29	100.0
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	33	81.8
Method 2—Larvae not sprayed, foliage sprayed		
(a) Tartar emetic 2 lb., brown sugar 4 lb.	34	100.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	30	100.0
(c) Tartar emetic 4 lb.	29	100.0
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	20	95.0
Method 3—Larvae flooded on blotting paper with insecticide, then placed on unsprayed leaves. (20 larvae per test)		
(a) Tartar emetic 2, lb., brown sugar 4 lb.	14	0.0
(b) Tartar emetic 4 lb., brown sugar 4 lb.	14	42.8
(c) Tartar emetic 4 lb.	15	20.0
(d) Tartar emetic 4 lb., sodium lauryl sulphate 6 oz.	16	6.2

Test C

Larvae, most of which were over half grown, were removed from the plant and placed in shallow boxes made of blotting paper and then sprayed at intervals of $7\frac{1}{2}$ minutes. Every 15 minutes groups of 20 larvae per treatment were removed from the box and placed on an unsprayed plant. The first group thus received one spray and was at once transferred; the second group received 3 sprays and was kept on the moist paper for 15 minutes; the third group received 5 sprays and remained on the paper 30 minutes; while the last group received 7 sprays and remained on the paper 45 minutes. The sprays used were: *(a)* tartar emetic-brown sugar 4–4–80, and *(b)* tartar emetic 4 lb., sodium lauryl sulphate 6 oz., and water 80 gal. They were applied July 26 at a temperature of 76° F. in an open insectary. Results are shown in Table 5.

TABLE 5.—MORTALITY OF GREENHOUSE LEAF-TYER LARVAE FOLLOWING DIFFERENT EXPOSURES TO TARTAR EMETIC SPRAYS. TREATED JULY 26, EXAMINED JULY 28

Treatment	No. applications	Exposure time, min.	No. larvae recovered	Mortality
				%
a	1	3 (approx.)	19	44.4
a	3	15	16	76.4
a	5	30	14	78.5
a	7	45	14	78.5
b	1	3 (approx.)	13	53.8
b	3	15	10	50.0
b	5	30	12	91.6
b	7	45	13	76.9

Observations of the larvae after they were transferred to the unsprayed plants showed that those which died did so within 2 days without apparently having done any feeding, and that in general those which survived were larger than those which were killed. The survivors fed actively on the plants and caused extensive injury.

Experiment 3. Tartar Emetic—Talc Dust on Larvae

A preliminary test was run with a dust consisting of 20% tartar emetic and 80% talc by weight against third to fifth instar larvae, in which 60 individuals resting on cotton gauze received a light coating of the dust on July 28, at an air temperature of 95° C., then were transferred to an untreated plant. Counts following the treatment gave the following cumulative mortality figures: July 29, 40.0%; July 30, 69.7%; July 31, 71.2%; and August 4, 88.8%.

In a second test 40 larvae in the third to fifth instars were placed on each of several small snapdragon plants and both larvae and plants given a moderately heavy coating of either 1, 5 or 10% tartar emetic—talc dust. The results are presented in Table 6.

TABLE 6.—EFFECT OF TARTAR EMETIC DUSTS ON THIRD TO FIFTH INSTAR GREENHOUSE LEAF-TYER LARVAE. APPLIED JULY 29; 40 LARVAE PER TEST

Date	Concentration of tartar emetic	No. larvae recovered	Mortality
	%		%
July 30	1	35	51.4
"	5	31	95.3
"	10	35	100.0
August 4	1	32	56.2
"	5	31	95.3
"	10	35	100.0

By August 4, the amount of feeding injury was large, moderate and very slight respectively on plants dusted with the 1, 5 and 10% mixtures.

It is of interest that the action of the dust was apparently faster when applied to both plants and larvae than when applied to the larvae only. In the former case the maximum mortality was reached in one day whereas in the latter the maximum kill was not obtained until 3 to 7 days after treatment.

Experiment 4. Residual Effect of Tartar Emetic on Eggs and Larvae

Snapdragons, sprayed with various tartar emetic mixtures a week previously were placed in cages with leaf-tyer adults for 24 hours. The resulting eggs hatched 6 days later, i.e., 12 days after the plants were treated. Mortality counts made 6 days after hatching are given in Table 7.

TABLE 7.—RESIDUAL EFFECT OF TARTAR EMETIC SPRAYS ON GREENHOUSE LEAF-TYER EGGS AND LARVAE. PLANTS SPRAYED JULY 21; EGGS HATCHED AUGUST 12, AND COUNTS MADE AUGUST 18

Treatment—amounts per 80 gal.	No. eggs (shells)	Egg mortality	Total no. larvae recovered	Larval mortality*
		%		%
(a) Tartar emetic 2 lb. Brown sugar 4 lb.	167	7.5	106	35.8
(b) Tartar emetic 4 lb. Brown sugar 4 lb.	80	15.0	16	25.0
(c) Tartar emetic 4 lb.	40	5.0	28	14.3
(d) Tartar emetic 4 lb. Sodium lauryl sulphate 6 oz.	88	4.5	40	23.3
(e) Check; water	59	0.0	40	2.5

* The larval mortality was calculated from the total larvae recovered.

This experiment indicated that tartar emetic retains its effectiveness against the larvae for at least 12 days on the foliage. It also affords some evidence of residual effect against the eggs. The addition of the sugar resulted in higher kills of both eggs and larvae. It is quite likely that the actual kill of larvae from the tartar emetic was higher than indicated by the percentage figures given, because, as will be noted in the table, a greater number of larvae were unaccounted for on the treated plants than on the check.

Experiment 5. Effect of Tartar Emetic on Adults, Eggs, and Larvae

Chrysanthemums were sprayed with tartar emetic—brown sugar 2–4–80, then placed in Riley cages, and adult moths, all less than 2 days old, at once added. No sex determination of the moths was made. Water was added to the soil, and dead moths recorded and removed from the cages daily. Three days after the last moth died the plants were examined for egg shells and larvae. Plants used in the check cages were sprayed with water just prior to adding the moths. Results for 2 tests started on September 22 and one on September 26 are summarized in Tables 8 to 10.

TABLE 8.—RECORD OF GREENHOUSE LEAF-TYER MOTHS CAGED ON CHRYSANTHEMUMS SPRAYED WITH TARTAR EMETIC-BROWN SUGAR 2–4–80

Cage no.	Date	Treatment	No. adults added	No. adults recovered
1	Sept. 22	Tartar emetic	25	14
2	"	Check—water	25	10
3	"	Tartar emetic	15	4
4	"	Check—water	15	5
5	Sept. 26	Tartar emetic	15	10
6	"	Check—water	15	10

TABLE 9.—LONGEVITY OF GREENHOUSE LEAF-TYER ADULTS IN CAGES WITH SPRAYED OR UNSPRAYED PLANTS

Date	Percentage cumulative mortality					
	Cage 1 treated	Cage 2 check	Cage 3 treated	Cage 4 check	Cage 5 treated	Cage 6 check
Sept. 22	0.0	0.0	0.0	0.0		
23	14.3	0.0	0.0	0.0		
24	57.2	10.0	0.0	0.0		
25	92.8	10.0	25.0	0.0		
26	100.0	30.0	25.0	0.0		
27		40.0	50.0	80.0	0.0	0.0
28		50.0	100.0	80.0	40.0	0.0
29		60.0		80.0	80.0	0.0
30		70.0		100.0	100.0	0.0
Oct. 1		80.0				0.0
2		80.0				20.0
3		80.0				20.0
4		100.0				50.0
5						50.0
6						80.0
7						100.0

TABLE 10.—RECORD OF EGGS AND LARVAE IN CAGES SPRAYED WITH TARTAR EMETIC, BASED ON COUNTS MADE THREE DAYS AFTER THE LAST MOTH DIED IN EACH CAGE AS INDICATED IN TABLE 9

Cage and treatment	Eggs			Larvae		
	Hatched	Dead	Mort.	Living	Dead	Mort.
			%			%
1 Tartar emetic	40	12	23.2	34	21	47.7
2 Check	109	1	0.9	195	2	1.0
3 Tartar emetic	41	2	4.6	6	7	53.7
4 Check	90	0	0.0	102	0	0.0
5 Tartar emetic	66	1	1.5	12	33	73.3
6 Check	112	3	2.6	153	0	0.0

The data in these tables bring out the following points of interest:

(a) The number of eggs laid in the check cages was considerably greater than in those treated with tartar emetic, being approximately 3, 2.5, and 3 times respectively as great in cages 1, 3 and 5, as in the corresponding checks.

(b) In the case of cages 1 and 2, approximately 6 times as many living larvae were on the check as on the treated plant; in cages 3 and 4, approximately 17 times as many as on the check; and in cages 4 and 5, approximately 13 times as many.

(c) Larval mortality as indicated by recovered living and dead larvae was negligible in the checks, but in the treated cages was 44.7, 53.7, and 73.7% respectively.

(d) There was some indication in cage 1 that tartar emetic had some effect on the eggs, but in the other two treated cages the egg mortality was not significantly different from the checks.

It will be noted that many adults were not accounted for in these tests and it is thought that spiders were responsible as several were seen removing dead moths. It is also apparent from the data in Table 10 that all the eggs were not accounted for because in several cases the total number of larvae exceeded the number of egg shells found. Some of the latter undoubtedly fell off the leaves before the count was made.

Experiment 6. Comparison of Tartar Emetic and Lead Arsenate in Controlling the Greenhouse Leaf-tyer

The previous experiments were all run on potted plants with comparatively small numbers of larvae, whereas this experiment was carried out on heavily infested snapdragons in a ground bed in a greenhouse compartment 11 by 16 feet, thus affording an opportunity of testing the two insecticides under conditions more like those in commercial greenhouses.

Snapdragons were set out in the ground bed early in October 1941, and 439 leaf-tyer moths liberated in the compartment between November 4 and December 1. On December 16, when the plants were heavily infested, the soil area was marked off into 4 rectangular plots and the following treatments applied: Plot A—tartar emetic-brown sugar 4–4–80, using a power greenhouse sprayer at 200 lb. pressure; Plot B—dusted with a mixture of tartar emetic 5 parts and talc 95 parts by weight, using a rotary type hand duster; Plot C—arsenate of lead 4 lb. to 80 gal. water applied with the power sprayer; and Plot D—check, sprayed with water. The air temperature at the time of treatment was 64° F.

RESULTS

Plots A and C were near the heating pipes on the west side of the compartment and were considerably more heavily infested at the time of treatment than the other two. This, combined with the fact that many dead larvae fell off the plants, made it difficult to evaluate accurately the degree of control obtained by the different treatments. On December 17, one day after treatment, an examination of 40 larvae per plot showed mortalities of 65% in Plot A, tartar emetic spray; 12.5% in Plot B, tartar emetic dust; 17.6% in Plot C, arsenate of lead; and 0.0% in the check. By December 27 the injury on the previously more lightly infested check plot had become much more severe than on any of the treated plots, while the injury on the latter plots had increased only slightly since treatment. Final observations on January 5 showed almost complete defoliation of the check plants with a large population of larvae present. Apparently about equal control was secured by the tartar emetic and arsenate of lead sprays, although a few larvae were still present. New foliage had been sent out on the plants in these two plots and it was largely uninfested. Moderate control appeared to have been secured by the tartar emetic dust although some plants were still fairly heavily infested.

Following the examination of January 5, a few uninfested plants in pots were placed among the old infested plants and all sprayed with tartar emetic-brown sugar 4–4–80. A second application of this spray was made on January 17, The new plants soon became infested with partly grown larvae which migrated from the old snapdragons. Many dead larvae could be found after the second treatment, and apparently not many newly

hatched larvae became established, but these two applications did not eradicate the infestation.

DISCUSSION

Further experiments are necessary to determine precisely the action of tartar emetic against all stages of the greenhouse leaf-tyer and its value under commercial greenhouse conditions. The data presented in this paper indicate strongly that tartar emetic kills both by stomach poisoning and by contact action, although in some of the experiments it was not clear which was primarily responsible. For example, in Experiment 2, it was shown that there was a high mortality of unsprayed larvae, particularly young ones, on foliage bearing a dry deposit of tartar emetic which would scarcely be expected to have any appreciable contact action. In numerous cases, however, it was observed that larvae hatching on a leaf carrying a dry deposit of tartar emetic would die after having eaten a bit of leaf no larger than the larva's head. The results obtained by spraying or flooding the larvae with the insecticide and then placing them on unsprayed foliage were rather erratic, in some cases the resulting kill being high and in others low. However, the fact that a higher kill was almost always obtained when both the larvae and the foliage were sprayed, than when only the foliage was sprayed, lends support to the supposition that some of the action is by contact. This was also true in the case of the dusts. Test C of Experiment 2, in which the mortality increased as the time of exposure to the tartar emetic solution was lengthened, also bears out the theory of contact action, although there is always the possibility that the larvae ingest some of the liquid before it dries and consequently do not need to swallow any plant tissue in order to carry the poison into the stomach.

In general, the tartar emetic in combination with brown sugar was more effective than when used with water alone, or in combination with a spreader. These differences are most pronounced in the data in Table 1. Just what role the sugar plays in increasing the mortality is not known, but the fact that larvae so often died on treated foliage after having done an extremely small amount of feeding, made it appear unlikely that the sugar acts as a bait. Its action in increasing kill is more likely that of giving a heavier deposit of the insecticide on the foliage by the formation of comparatively large drops. The fact that the addition of spreaders, which would probably result in smaller deposits owing to run-off, usually lowered the kill, lends support to this probability. The possibility that a sugar solution alone might kill many young larvae by drowning was investigated, but this did not occur even at sugar concentrations double those used with tartar emetic. The test was run on September 18 at a temperature of 87° F. Groups of 10 larvae each, less than 24 hours old, on ageratum plants were sprayed with the following solutions: A—brown sugar 4 lb. to 80 gal. water; B—brown sugar 8 lb. to 80 gal.; C—tartar emetic-brown sugar 4–4–80; and D—water. The larvae were observed under a low power microscope and little difference was noticed in their actions, although the leaves sprayed with the sugar solutions remained moist for 1 hour while those sprayed with water dried off in 30 minutes. None of the larvae had any green food visible in their intestines prior to treatment, but in all cases except where the tartar emetic was used, after a period of about 30 minutes spent in relative inactivity in the film of moisture,

feeding movements started and green food was noticed in the intestine. Only one of the 30 larvae treated with sugar or water died within the 24-hour period of observation. However, in the case of the tartar emetic sugar spray, although the larvae showed apparently normal movements for an hour after treatment, not one ingested any plant tissue and all were dead within 24 hours.

There was little difference between the results with tartar emetic at rates of 2 lb. or 4 lb. per 80 gallons water, although the latter sometimes gave a slightly higher kill.

The data in Experiment 5 are of particular interest in showing the effect of tartar emetic on the adults. The moths were transferred to the cages before the spray had dried and were thus exposed to droplets of liquid for at least 2 or 3 hours. Unfortunately no corresponding tests were carried out in which adults were exposed to a dry spray residue so it is not known whether the availability of the poison was confined to the relatively short period prior to the evaporation of the water from the solution. In one small scale test a few moths were exposed to foliage bearing *(a)* fresh droplets of a solution of tartar emetic-brown sugar 4–4–80 plus methylene blue, and *(b)* the dried residue of this solution. Dissection of the moths 48 hours later revealed the presence of the dye in the intestines of moths from both treatments. There was no visible condensation of moisture during the 48-hour period on the foliage with the dry residue, but possibly enough did condense to make feeding possible.

Table 10 gives some evidence that tartar emetic kills a small percentage of eggs. In view of its action on larvae, adults, and possibly on eggs, there is the possibility that repeated applications might bring about elimination of an infestation more rapidly than would be expected of arsenate of lead.

Experiment 3 showed that dusts containing from 5 to 10% tartar emetic by weight may kill from 93 to 100% of even the larger larvae. The fact that the 5% dust in Experiment 6 failed to give as good control as the sprays was due, it is thought, to the difficulty in getting a sufficiently heavy and even coating on all parts of the dense low-lying plants.

Under conditions approximating those of a commercial greenhouse, it was shown that two applications of tartar emetic spray, although lowering the population to a marked degree, could not be expected to give complete control. Further work under larger greenhouse conditions will be carried on to determine the commercial value of tartar emetic treatments.

SUMMARY

Tartar emetic sprays were shown to cause high mortality of greenhouse leaf-tyer larvae, the early instars being more susceptible than the later. The addition of brown sugar increased the effectiveness of the spray, while the addition of spreaders lowered it. Dusts containing from 5 to 10% tartar emetic were also effective against the larvae. Data are presented to show that larvae are killed by both stomach poisoning and by contact. Tartar emetic residues on the foliage resulted in shortening the life of the moths, reducing the number of eggs laid, and increasing the mortality of the resulting larvae.

MALLING STOCKS AND FRENCH CRAB SEEDLINGS AS STOCKS FOR FIVE VARIETIES OF APPLES. III.

W. H. Upshall[1]
Horticultural Experiment Station, Vineland, Ontario

[Received for publication March 1, 1943]

The Malling apple rootstock orchard at the Ontario Horticultural Experiment Station completed its thirteenth year in the fall of 1942. Two previous reports on this orchard, at the conclusion of the fifth and eighth years, have been published (4, 5). In the fall of 1942 the removal of half the fillers became necessary. This meant the elimination of all trees on the Malling II root. The results to date are analyzed under various headings and the more important data are given in tabular and graphic form.

GROWTH

Weight of Prunings

The total accumulated weight of prunings has risen sharply in the last three years (Fig. 1) but even so the pruning would be considered by growers as moderate or less in amount. In a general way the weight of prunings is positively correlated with the size of the trees. French Crab and Malling XVI trees are nearly the same size (Figures 2–6) and the weights of prunings bear the same relation to one another. The same condition prevails between Malling I and II, but, as in tree size, there is a considerable difference between French Crab and Malling XVI trees on the one hand and Malling I and II on the other. It is quite evident that pruning will almost inevitably tend to reduce size differences between trees on rootstocks of varying growth potentialities but yet it must be recognized that pruning is an essential operation in commercial orchards.

Trunk Size

Except in the McIntosh variety, the two standard rootstocks, French Crab seedlings and Malling XVI, have maintained the 1937 order in trunk size, the former in the lead in three varieties and the latter in two (Figures 2–6). However, none of these differences are significant. Malling I and II trees have significantly smaller trunks than French Crab and Malling XVI trees except for Melba on Malling II which is bracketed with the two standard rootstocks (Figure 3). It is only in the Melba variety also that Malling I and II differ significantly in trunk size. In all varieties however, the Malling II trees are the larger but showing some signs of losing their lead over Malling I trees.

Height

In height of tree also, French Crab and Malling XVI trees are in one class and Malling I and II in another class with no consistent differences between the members of each class (Table 1). The greatest height reduction by the use of Malling I and II rootstocks has been with the Spy variety and the least, with Melba.

[1] Chief in Research.

TABLE 1.—MEAN HEIGHT OF TREES, THIRTEENTH YEAR IN ORCHARD*

	French Crab	XVI	I	II
	metres	metres	metres	metres
R. I. Greening	4.4	4.3	3.7 (11)	3.6
Melba	4.8 (13)	4.9	4.6	4.6 (12)
Delicious	4.9	4.8	4.6	4.4
Spy	5.4	5.4	4.4	4.6
McIntosh	5.3 (13)	5.2	4.6	4.5

* 14 trees of each combination except where number is given in brackets. These numbers apply to all succeeding tables and graphs.

Spread

Considering all 5 varieties, there has been just about the same reduction in spread (Table 2) as in height by the use of Malling I and II rootstocks. Again variety differences are in evidence, McIntosh on Malling I and II being close to the standard trees in spread, and R. I. Greening, very much less than the standard trees. The differences in area of cross-section of trunk (Figures 2–6) between the French Crab and Malling XVI trees on one hand and Malling I and II on the other hand are greater than the differences in height and spread. There is no way of knowing which measure gives the best index of relative tree weights or bearing areas.

TABLE 2.—MEAN SPREAD OF TREES, THIRTEENTH YEAR IN ORCHARD

	French Crab	XVI	I	II
	metres	metres	metres	metres
R. I. Greening	7.0	7.0	5.4	5.7
Melba	6.2	6.5	5.6	5.8
Delicious	6.8	6.7	5.8	6.0
Spy	5.7	5.9	5.0	5.4
McIntosh	6.8	7.0	6.6	6.5

Anchorage and Compatibility

Trees on French Crab seedlings and Malling XVI have stood up against some very strong winds. The same could have been said for trees on Malling I and II if Delicious had not been included in the test. In the thirteenth year, out of 14 Delicious trees of each combination, 3 on Malling I and 2 on Malling II have gove over so far that they interfere with cultural operations and require straightening and support. The trunks of some other trees of these combinations are showing varying lesser degrees of inclination. Sudds and Marth (3) report poor anchorage for trees grown on the Malling I root in West Virginia.

The only evidence of incompatibility has been with R. I. Greening on Malling I where two trees out of 14 have been broken at the union by

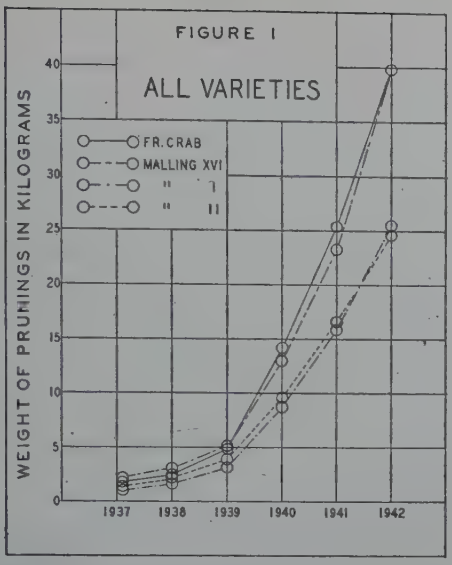


FIGURE 1. Accumulated weight of prunings per tree, 1937–42, averages of five varieties.

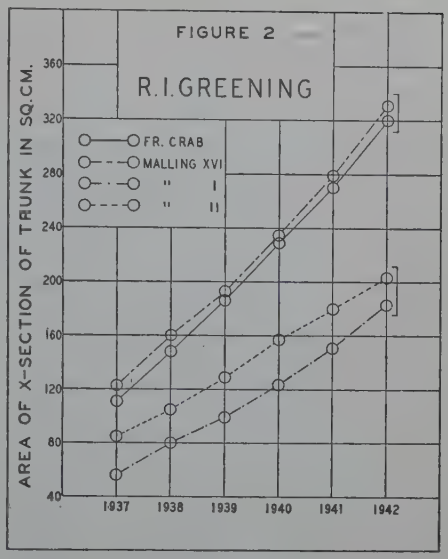


FIGURE 2. Mean area of cross-section of trunk, 1937–42. 1942 figures within a given bracket are not significantly different.

heavy winds, one in June, 1933, and the other in June 1938. However, aside from breakage, there have been no other evidences of incompatibility in this combination.

YIELD OF FRUIT

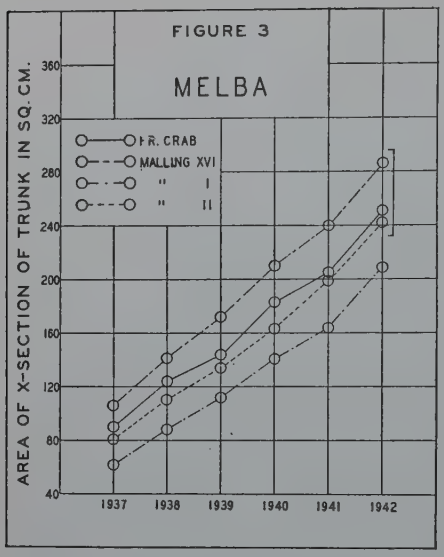
Comparing varieties, the yield of fruit is notable for its differences but not so between rootstocks when considered within a given variety (Figures 7–11). So close are they that there are no significant differences in R.I. Greening, Melba or McIntosh, and only between the extremes in Delicious. In Spy however, Malling I and II trees which began bearing before the standard trees, are still ranked as significantly more productive.

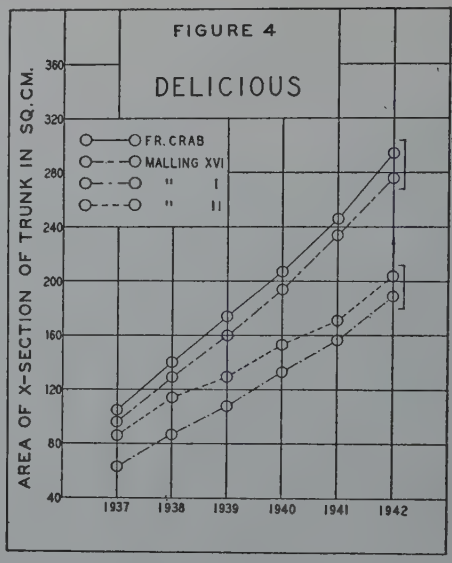
It is quite apparent that, having regard to their smaller size, the Malling I and II trees have been more productive than the trees on the standard rootstocks. This difference can be shown by determining the yield per 100 square centimetres of trunk cross-section (Table 3). By this computation Malling I trees have been the most productive in 4 varieties and Malling II in 1 variety.

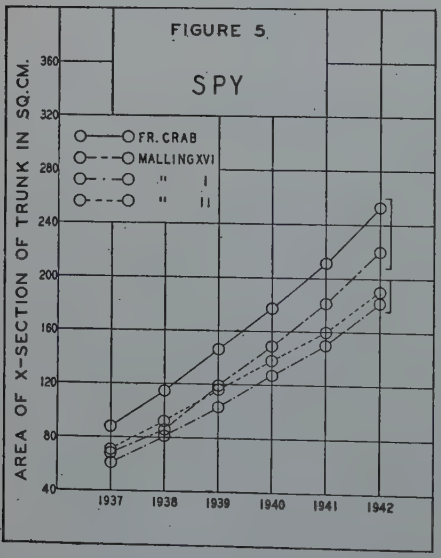
TABLE 3.—YIELD OF FRUIT PER 100 SQ. CM. OF TRUNK CROSS-SECTION, INCLUDING THE THIRTEENTH YEAR

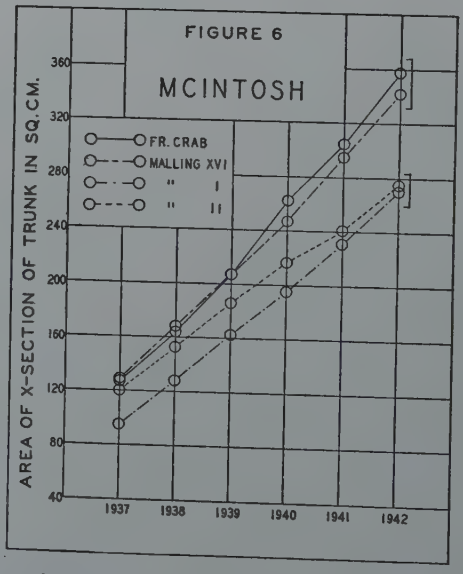
	French Crab	XVI	I	II
	Kgm.	Kgm.	Kgm.	Kgm.
R. I. Greening	137	111	190	205*
Melba	110	123	133*	125
Delicious	105	103	146*	117
Spy	46	37	98*	89
McIntosh	178	192	228*	198

* High reading for each variety.





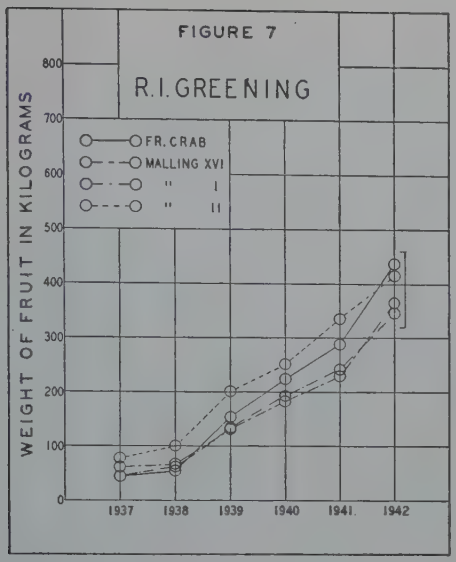


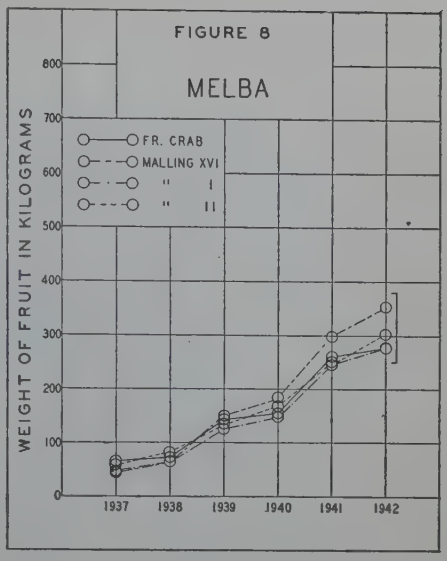


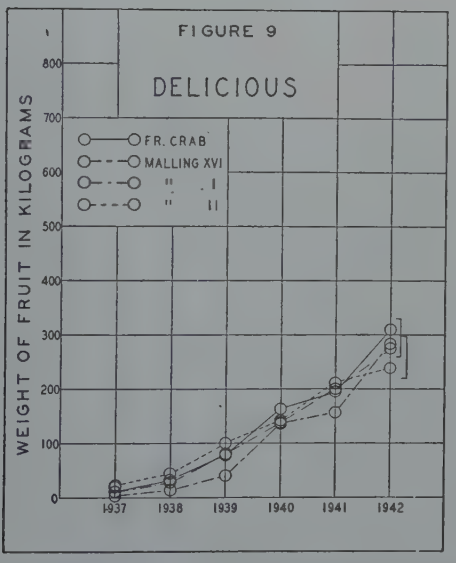
FIGURES 3–6. Mean area of cross-section of trunk, 1937-42. 1942 figures within a given bracket are not significantly different.

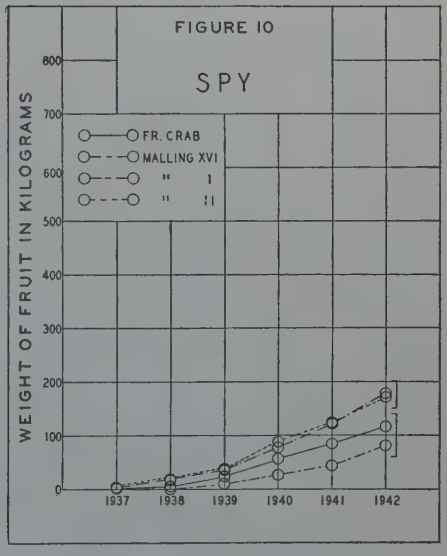
Averaging the yields of all varieties and putting them on the basis of 100 for French Crab seedling trees, the yield relations on fixed area of trunk cross-section and on fixed area of branch spread are as follows:

	French Crab	XVI	I	II
On fixed area of trunk cross-section	100	98	138	128
On fixed area of branch spread	100	95	130	120









FIGURES 7–11. Accumulated yields of fruit per tree, 1937–42. 1942 figures within a given bracket are not significantly different. See page 543 for Figure 11.

Both of these bases show Malling I trees as most productive with Malling II trees in second place.

Fruit dropping on the ground just previous to picking was recorded separately but added to the total yields. There was no evidence of rootstock effect on fruit dropping nor was there any other sign of rootstock effect on time of maturity of the fruit. The same could be said for storage tests.

GRADE OF FRUIT

Commercial Grade

Beginning in 1936 and continuously thereafter the whole crop or a part of the crop from each tree, usually one bushel, was graded. In that all trees in this orchard received similar treatment the grading figures (Table 4) very largely express relative surface colour, except in the green-skinned R. I. Greening variety. Delicious and Spy on French Crab seedlings are of an inferior colour strain to the other trees and McIntosh on the same rootstock is a slightly better colour strain than the other McIntosh trees. This condition very much reduces the value of these combinations as a basis for colour comparisons. However, on the whole, Malling I and II trees have borne crops grading a slightly higher proportion of No. 1 fruits than the Malling XVI trees, the only exception being in McIntosh where, 5 years out of 7, fruits from the Malling XVI trees were of higher grade than those from Malling I and II trees.

TABLE 4.—No. 1 APPLES AS PERCENTAGES OF THE TOTAL CROP, AVERAGES OF THE CROPS OF 1936–42 INCLUSIVE

	French Crab	XVI	I	II
	%	%	%	%
R. I. Greening	71	65	73	72
Melba*	27	26	29	32
Delicious	66†	83	85	84
Spy*	47†	40	51	61
McIntosh	71†	77	61	68

* 1937–42.

† Different colour strain to the other trees and therefore not comparable to them.

Size

The apples from each combination were divided into 4 caliper classifications, above 7 centimetres being the highest one. The percentage of the crop falling into this class has been used as an index of size of fruit (Table 5). It shows that French Crab and Malling XVI trees give very similar results, likewise Malling I and II, but between these groups there appears to be some difference in favour of the former.

TABLE 5.—APPLES ABOVE 7 CM. IN DIAMETER AS PERCENTAGES OF THE TOTAL CROP, AVERAGES OF THE CROPS OF 1936—42 INCLUSIVE

	French Crab	XVI	I	II
	%	%	%	%
R. I. Greening	76	75	70	75
Melba	43	39	35	26
Delicious	65	68	55	50
Spy*	79	81	71	74
McIntosh	66	73	67	64

* 1937–42

VARIABILITY

The variability in area of cross-section of trunk has changed but little since 1937 (Table 6). In this comparison Malling I trees are now just as uniform as Malling II trees, both of them being less uniform than French Crab and Malling XVI trees. Calculated on yields, all of the coefficients of variability are much larger than on trunk measurements. The tendency to a biennial bearing habit, more or less prominent in each variety, may account for part of this difference but trunk measurements should also be affected by this habit. Since 1937 the coefficients of variability of yields have been reduced considerably but it is questionable if they will ever become as low as those based on trunk measurements. On the whole, French Crab seedling rootstocks have given no more variable growth or fruiting than the clonal rootstocks. This is in accord with the findings of Southwick and Shaw (1) and Sudds (2). McIntosh on Malling XVI is outstanding in uniformity of trunk size and fruit yields. This variety largely accounts for the difference in variability of yields between French Crab seedlings and Malling XVI.

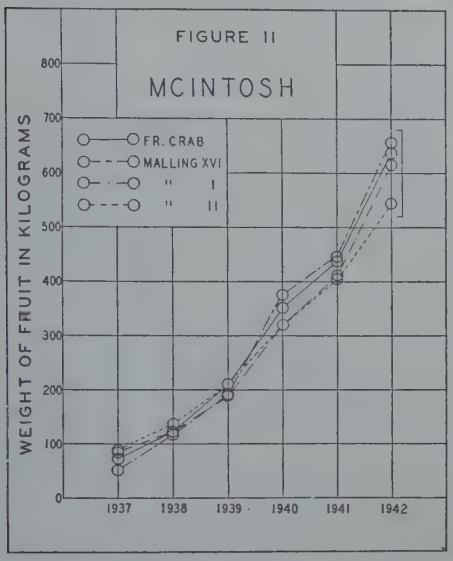


TABLE 6.—COEFFICIENTS OF VARIABILITY IN 1937 AND 1942, MEAN OF FIVE VARIETIES

	French Crab	XVI	I	II
Area of cross-section of trunk 1937	19	18	29	21
Area of cross-section of trunk 1942	18	18	23	23
Accumulated yield to 1937*	59	54	49	46
Accumulated yield to 1942	35	30	32	28

* Spy not included at this date owing to insufficient production.

MALLING IX

Since the last report on this orchard (5), and to be exact, in 1941, the Spy trees on Malling IX died, probably altogether as a result of a tile drain stoppage at the time of building a new highway nearby. One R. I. Greening tree became loose from its support and broke off just below the union. With these exceptions all trees on this rootstock are growing and producing well. Based on area of cross-section of trunk, the trees are now, in the thirteenth year, from 19% of the size of the French Crab trees in Melba to 24% in R. I. Greening, Delicious and McIntosh. Two years ago,

while the Spy trees on Malling IX were still normal, their trunk size was 57% of that of Spy on French Crab, relatively much less difference than in the other varieties. The yield per tree fell below that of French Crab trees in the following years for each variety; McIntosh, 7th; Melba, 8th; R. I. Greening, 10th; Delicious, 11th; and Spy on Malling IX was still in the lead at the end of the 11th year. Including the 13th year R. I. Greeinng and McIntosh on French Crab have more than doubled the yield of these same varieties on the Malling IX root. Trunk sizes and accumulated yields of the Malling IX trees are given in Table 7. Owing to the small numbers of each combination the data should not be given great weight.

TABLE 7.—GROWTH AND YIELD OF TREES ON MALLING IX AT END OF THE THIRTEENTH YEAR

	Number of trees	Mean area of cross-section of trunk	Accumulated yield per tree
		sq. cm.	Kgm.
R. I. Greening	2	76.5	190
Melba	6	48.5	150
Delicious	3	70.2	215
McIntosh	4	87.2	273

DISCUSSION

In this test Malling XVI rootstocks have not yet proved to be superior to French Crab seedlings as rootstocks for standard-sized trees, the only exception to this conclusion being in the McIntosh variety where there has been a suggestion of greater uniformity of growth and yield and improved fruit colour. With the R.I. Greening variety Malling XVI rootstocks looked very promising in the early years but are now falling down in yield of fruit.

With questionable anchorage in Delicious and tendency to weak union in R. I. Greening some doubt is cast on the advisability of using Malling I rootstock in commercial orchards in Ontario. Yet, with its high yield per unit of branch spread, trial plantings of McIntosh, Spy and Melba on this rootstock may be justified. In the early years Malling II looked to be a better proposition as a semi-dwarfing rootstock than Malling I, but at present its superiority over the latter is in some doubt. Both rootstocks however are giving a larger tree than expected and perhaps still too large for the grower who desires to reduce the cose of production by the use of trees of low stature. On the average, Malling I and II trees are now approximately three-quarters the size of trees on French Crab seedlings and size differences are tending to become greater.

Trees on the Malling IX root fulfil the requirement of low stature but their need of continuous and substantial support is a formidable stumbling block to their use in commercial orchards though not necessarily for back-yard gardens. To growers who would pay careful attention to staking and tying trees on Malling IX, very high per acre yields ought to be possible owing to their precocity and adaptability to close planting.

SUMMARY

This is the third report on the Malling apple rootstock orchard at the Ontario Horticultural Experiment Station. In the fall of 1942 the trees had completed 13 years' growth in the orchard and the data presented completes the records up to this time. The results can be summarized as follows:

1. In size of tree there are no significant differences between French Crab seedlings and Malling XVI. Malling I and II have, with one exception, produced significantly smaller trees than the above rootstocks. On the average they are about three-quarters the size of trees on French Crab seedlings.

2. Malling I trees have suffered some breakage at the union in the R. I. Greening variety and both Malling I and II trees have shown a tendency to blow over when Delicious was the scion variety.

3. The yields within a given variety have been very close to one another and usually not statistically different, the smaller trees on Malling I and II making up in productiveness most of what they lost in consequence of smaller bearing area.

4. Usually Malling I and II trees have had a slightly higher proportion of Grade No. 1 fruit but slightly smaller size than the French Crab seedling and Malling XVI trees.

5. Trees on French Crab seedlings have been no more variable in growth or fruiting than trees on the clonal rootstocks.

6. Trees on the Malling IX root are very much dwarfed, have fruited well for their size, but have shown very definitely the need for continuous and substantial support.

ACKNOWLEDGMENT

The author is indebted to Mr. J. R. vanHaarlem for the graphs used in this paper.

REFERENCES

1. Southwick, L. and J. K. Shaw. Further notes on the Malling Clonal Stocks in relation to McIntosh and Wealthy. Proc. Amer. Soc. Hort. Sci. 36 : 133-137. 1939.
2. Sudds, R. H. The comparative performance of several standard apple varieties on certain rootstocks, principally the clones Malling I, II, and XIII. Proc. Amer. Soc. Hort. Sci. 37 : 311-318. 1940.
3. Sudds, R. H. and P. C. Marth. Wind damage to apple trees on selected rootstocks, Kearneysville, West Virginia, July 28, 1940. Proc. Amer. Soc. Hort. Sci. 38 : 299-304. 1941.
4. Upshall, W. H. Malling stocks and French Crab seedlings as stocks for five varieties of apples. I. Sci. Agr. 15 : 535-541. 1935.
5. Upshall, W. H. Malling stocks and French Crab seedlings as stocks for five varieties of apples. II. Sci. Agr. 18 : 370-378. 1938.

FURTHER APPLICATIONS OF METHYL BROMIDE AS A FUMIGANT[1]

H. A. U. MONRO[2] AND R. DELISLE[3]
Division of Plant Protection, Montreal, P.Q.

[Received for publication February 15, 1943]

Since the year 1936 the use of methyl bromide as a fumigant has increased very rapidly on the North American Continent and its extensive adoption has fully justified the prediction of those who first employed it. In view of its boiling point of 40.1° F., low compared with many fumigants, its ready adaptation to atmospheric fumigations was fully appreciated from the first, but its subsequent wide use has brought out the fact that it is not readily adsorbed by many commodities at normal pressures, and its vapours are thus able to diffuse fairly rapidly through material without the aid of circulating fans.

In this paper an account is given of some of the uses to which methyl bromide was put during 1941 and 1942 at the Fumigation Station, Dominion Department of Agriculture, Montreal, Quebec.

FUMIGATION OF IMPORTED BROOMCORN

Since the outbreak of war in 1939 the importation into Canada of broomcorn from countries other than the United States has been exclusively from the Argentine. All this material has travelled by boat to ports on the Atlantic seaboard of the United States and then been shipped in tightly closed cars to Montreal for fumigation. On opening these cars on arrival in Montreal during the summer months, it was found that several species of stored product insects, notably the Angoumois grain moth *Sitotroga cerealella* Oliv. and the rust-red grain beetle *Laemophloeus ferrugineus* Steph., were very numerous, in addition to any foreign pests which might be present in the bales. For a variety of reasons it was considered desirable to apply some treatment inside each car before it was unloaded, to prevent the escape of these insects and to disinfect the car itself before releasing it for the transportation of other commodities.

Atmospheric Fumigation Tests

Preliminary experiments in a small vault at atmospheric pressures had shown that larvae of the corn borer *Pyrausta nubilalis* Hbn. were very susceptible to the vapours of methyl bromide at comparatively low doses and times of exposure, even when buried inside the bales of broomcorn. In these experiments circulation with a small fan was employed for only 5 minutes at the beginning of each test, and subsequent results obtained under practical conditions would seem to indicate that fan circulation is unnecessary for longer exposure periods, and that the adsorption of the fumigant by this commodity does not prevent an ultimate even distribution of the gas, at temperatures of 60° F. and above, with the doses used. The results obtained in the small scale tests are summarized in Table 1.

[1] Contribution No. 32 from the Plant Protection Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Supervising Inspector.
[3] Agricultural Assistant.

TABLE 1.—ATMOSPHERIC FUMIGATION OF CORN BORER LARVAE WITH METHYL BROMIDE*

Dosage CH_3Br lb. per 1000 cu. ft.	Bale temperature		Mortality of corn borer larvae																‡Adults emerged summer 1941
			In naturally infested stalks								Larvae in gelatin capsules								
			First examination 9/5/41				Second examination 20/5/41				First examination 29/4/41				Second examination 20/5/41				
	Before	After	A†	D	T	%	A	D	T	%	A	D	T	%	A	D	T	%	
.75	62	64	90	3	93	3.2	62	31	93	33.3	19	1	20	5	16	4	20	20	7
1.0	64	64	43	17	60	28.3	23	37	60	61.7	17	3	20	15	11	9	20	45	0
1.25	61	62	78	43	121	35.5	42	79	121	65.3	15	5	20	25	9	11	20	55	1
1.5	59	64	50	73	123	59.2	13	110	123	89.4	10	10	20	50	2	18	20	90	0
1.75	62	64	25	134	159	84.2	7	152	159	95.6	11	9	20	45	3	17	20	85	0
2.0	60	64	13	131	144	90.9	3	141	144	97.9	11	9	20	45	1	19	20	95	0
2.25	63	63	2	94	96	97.9	0	96	96	100	—	—	—	—	—	—	—	—	—
2·5	63	63	1	113	114	99·2	0	114	114	100	—	—	—	—	—	—	—	—	—

* Larvae of the corn borer *Pyrausta nubilalis* Hbn. collected at Ile Bizard, P.Q., October 1940 and kept at 40–45° F. until fumigation, April 21–25, 1941. Exposure period of 4 hours, vault temperature 60° F., fan circulation for 5 minutes only after introduction of gas. Bale of broomcorn weighing about 70 pounds placed in 30 cubic foot vault for each treatment. Larvae in gelatin capsules placed inside each bale by means of stick pierced with holes one inch apart.

† A—Alive. D—Dead. T—Total.
‡ From larvae kept in gelatin capsules only.

An interesting phenomenon is the large percentage of survivors living some time after exposure, but which subsequently died after failing to progress to the next stage of their life history. This effect of methyl bromide has been noticed especially with lepidopterous larvae. Many survivors manifest nervous and unco-ordinated movements which may persist for many weeks before they finally succumb. In connection with quarantine treatments this behaviour will have to be investigated further, as the presence of survivors who live for a few months, even though they subsequently succumb without further development, would rule out for the time being a statement that 100% kill had been obtained.

These results[4] were analysed statistically following the method of Bliss (1), as discussed by Fisher and Yates (4). With the logarithm of the dosage plotted against the kill in terms of probits, a straight line relationship is obtained from the data yielded by the two counts made with an 11-day interval, as shown in Figure 1. In fitting the lines, the two lower

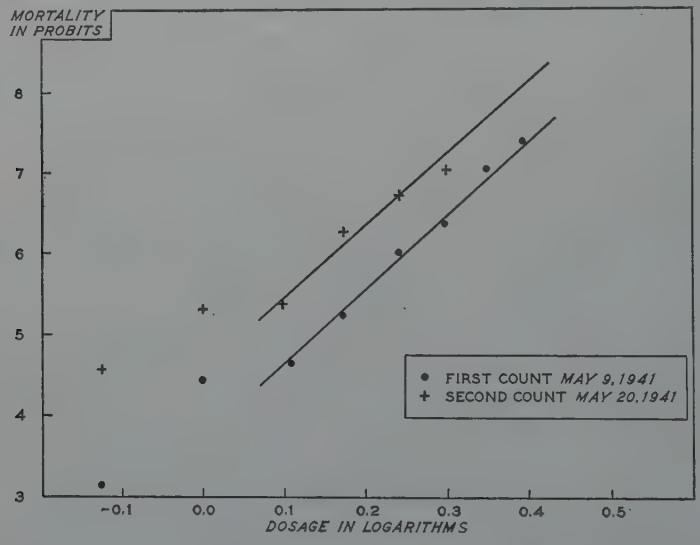


FIGURE 1. The relationship between mortality of *Pyrausta nubilalis* Hbn. in probits and the logarithm of dosage of methyl bromide in pounds per 1000 cubic feet for exposure period of four hours and temperature 60 degrees F. Counts made on May 9 are shown with dots and on May 20 with crosses.

points of each set were omitted and when this was done the fit was good, i.e., the probability of χ^2 was between 0.8 and 0.7 in each case. There is precedent for this omission since, as discussed by Bliss (2), such lower points often fall away from the line of main relationship. It will be noted that the two lines are approximately parallel.

The fact that equally good fits were obtained from the data of May 9 and May 20 is reassuring, in that it gives confidence of the quantitative treatment in either case. The importance of the time of examination is seen from the clear separation of the lines. From the fact that the two lines are so nearly parallel, separated in the horizontal direction by a distance of about 0.09, it is known that a concentration 23% higher was required to secure any given kill on May 9 than on May 20.

[4] The data was submitted to Dr. Geoffrey Beall of the Chatham Laboratory, Division of Entomology, Science Service, who kindly made the analysis presented in Figure 1.

Railroad Car Fumigation

As experiments on a small scale had shown such promise it was decided to use this fumigant for treating all railroad cars arriving with broomcorn during the warm months of 1941. The railways were requested to ship this material only in refrigerator cars or up-to-date air-tight steel box cars. For the most part this request was complied with, but in view of the demand for railroad equipment in the present crisis, cars were occasionally used which were unsuitable for fumigation.

The procedure was to apply the methyl bromide to the cars late in the afternoon and to open them up early the following morning, thus allowing an exposure period of 16 to 18 hours without any delay in the handling of the goods. In the case of refrigerator cars the only preparation necessary was the blocking of the drains from the ice bunkers with moist newspapers, but in the case of steel box cars masking tape or brown paper and flour paste were employed to seal the doors adequately. The temperatures which prevailed at this time in the bales and in the free space of the cars varied from 65° to 85° F. From results obtained during 1941 it was found that a dose of 2 pounds of methyl bromide per 1000 cubic feet of car space for an exposure period of 16 to 18 hours produced complete mortality of all the insects found in the bales or in the free space of the cars. Also all test corn borer larvae in naturally infested stalks or in capsules, and all test granary weevils, *Sitophilus granarius* L., many of which were completely buried by means of sticks in the centre of the bales, were all killed. These results were obtained in cars which were fully loaded with bales of broomcorn, and no circulation of the fumigant by fans or any other means was employed. However, if any slight leaks of the methyl bromide were detected with the aid of the Halide Leak Detector, good kills inside the bales were not obtained, although insects flying free in the car were always controlled. Unless, therefore, adequately air-tight equipment is employed this atmospheric fumigation in cars could not be adopted for quarantine purposes, but in this instance its object was achieved, namely, to prevent escape of insects during the unloading of the cars.

Under these practical conditions doses of 1.0 and 1.5 pounds per 1000 cubic feet were also tried and the indications were that, under ideal circumstances, the latter amount would be adequate, but that a dose of 1.0 pound was not sufficient to produce a toxic concentration in all parts of the bales during the 18-hour exposure.

In this work the fumigant was dispensed from cylinders, from a special methyl bromide applicator of 12 pounds capacity, or from 1-pound cans. In every case copper tubing was led through a narrow crack left by the almost completely closed door of the car. To begin with a "T" was employed to carry two 10-foot lengths of copper tubing towards each end of the car, but latterly a single tube 10 feet long, projecting well into the car and quickly withdrawn after the application of the fumigant, was found to be quite satisfactory.

Vacuum Treatments

The standard vacuum treatment for imported broomcorn has called for the use of live steam or, more latterly, hydrocyanic acid gas as described by McLaine and Monro (7). Experimental tests had shown that methyl

bromide also showed promise for the vacuum fumigation of broomcorn, and importations of this commodity were treated with this gas, under strict observation, during the fall of 1941 and the winter of 1941 and 1942.

Larvae of the corn borer collected locally during September 1941 were used as the principal test insects, and as an additional check adults of the granary weevil *Sitophilus granarius* L. were placed in gelatin capsules in small holes 1 inch apart pierced in specially modified broomsticks which were thrust inside the bales. The bales were of Argentine origin, with dimensions 50 × 36 × 24 inches, weighing approximately 350 pounds each, 20 of which could be treated at one time in the vault of 1200 cubic feet capacity.

At the commencement of this project, when the temperatures in the bales were high, the schedule which gave complete mortality of both the borers and the weevils, whether the latter were retained in the naturally infested stalks or placed in gelatin capsules in the sticks in the bales, called for a dose of 2.5 pounds of methyl bromide per 1000 cubic feet in a sustained vacuum of not less than 2 inches of absolute mercurial pressure for a period of 2 hours, with bale temperatures of 60° to 70° F. and vault temperatures of 75° to 85° F.

The stalks containing the borers were stored in a sheltered place out of doors and brought in either one day before or immediately preceding the fumigation treatments. As the weather became colder it was noted that these larvae showed an increased resistance to the above treatment, especially those not allowed to warm at room temperatures before fumigation. This resistance manifested itself by the appearance of an increasing proportion of moribund "nervous" larvae as described in the foregoing account of the atmospheric treatments. All these larvae finally succumbed without developing to pupae, but some lived for 2 or 3 months after treatment.

The quarantine requirements of 100% kill was thus ultimately satisfied, but this condition would not be desirable in quarantine treatments which are not under continuous technical supervision, as observed in the present case. Furthermore, at temperature below 60° F. complete mortality of the weevils near the centre of the bales was not obtained. To give a margin of safety, therefore, the exposure period was extended to 2.5 hours, with the attainment of complete kills of borers and weevils at bale temperatures at or above 60° F. It is interesting to note that in January, 1942, there was evidence of a marked decrease in the resistance of the borers which had been stored out of doors.

At present, therefore, the vacuum treatment for importation of Argentine broomcorn calls for a dose of 2.5 pounds of methyl bromide per 1000 cubic feet of vault space in a sustained vacuum of not more than 2 inches of absolute mercurial pressure for a period of 2.5 hours, with vault and bale temperatures of not less than 75° and 60 °F. respectively.

Further investigations are being made with bales at lower temperatures using higher doses with and without increased exposure periods.

Residues of Gaseous Methyl Bromide in the Bales

In common with all toxic gases used as fumigants, methyl bromide is dangerous if precautions are not taken to avoid breathing the vapours. Fatalities have been reported following exposure to this compound (6),

either alone or in combination, due, apparently, to carelessness, lack of adequate knowledge of its properties, or overconfidence bred of familiarity with its use. The concentrations liable to produce human fatalities are fairly well understood. A recent study of some importance is that of Watrous (10), who reports on the response of 90 employees continuously exposed to low concentrations of methyl bromide during a period of 2 weeks while filling small glass ampoules with this compound, when cooled to a liquid. Thirty-three of these persons developed mild systemic symptoms, although for the most part they were exposed to concentrations of less than 35 parts per million, which would cause no green colouring of the "Halide Leak Detector" used for detecting the vapours. The exact length of the working day involved in this manufacturing operation is not given by this author.

TABLE 2.—CONCENTRATIONS OF GASEOUS METHYL BROMIDE FOUND IN THE FREE SPACE OF VAULT FOLLOWING FUMIGATION OF BROOMCORN AND VARIOUS METHODS OF AERATION

A. In small experimental vault of 30 cubic feet capacity—fumigation at the rate of 2000 pounds of broomcorn exposed to 2 pounds of methyl bromide per 1000 cubic feet. All vacuum readings given in inches of absolute mercurial pressure.

Exposure and subsequent treatment	Interval of time in hours before sample taken	Mg. per litre at 85° F. 760 mm. pressure	Parts per million by volume
1. Vacuum sustained fumigation at 1" for 3 hours			
A. One Airwash to 2"	1	3.5	916
B. Two airwashes to 2"	1	1.3	340
2. Vacuum sustained fumigation at 1" for 3 hours			
A. Pumping air through door 5 minutes after 2 airwashes to 2" absolute	1	1.23	312
B. After "A"—Bale outside in open 40 min. and then replaced in vault	1	.14	37
3. Atmospheric 24 hours			
A. Pumping air through door 10 minutes	1	1.6	419
B. After "A"—Bale outside in open 20 min. and then replaced in vault	1	.55	144
C. Same as "B" after 18 hours	18	1.27	333

B. Fumigation in commercial vault of 1200 cubic feet capacity at the rate of 6000 pounds of broomcorn exposed to 2.5 pounds methyl bromide per 1000 cubic feet in a sustained vacuum fumigation at 2 inches of absolute pressure for 2 hours. Bale and vault temperature 75° F.

Exposure and subsequent treatment	Interval of time in hours before sample taken	Mg. per litre at 75° F.	Parts per million by volume
1. Immediately after two airwashes to 2" abs.	nil	A. .425 B. .472	109 121
2. In vault before removal of bales	1	A. 2.36 B. 2.37	606 609
3. In storage rooms after aeration in outside air one hour	18	Two samples did not show any detectable amount of methyl bromide.	

In connection with the possible use of this fumigant in the general fumigation of broomcorn, some tests were conducted on the concentrations of gas found after different degrees of air washing and ventilation had been carried out. These results are summarized in Table 2. The tests were made with the apparatus devised by Dr. H. C. Dudley of the United States Public Health Service, Washington, D.C., employing a modification of Volhard's method for the determination of bromide. Both apparatus and method have been previously described (8). Specially constructed small bales of broomcorn weighing about 70 pounds each were placed in the experimental vacuum fumigation vault of 30 cubic feet capacity. The samples of gas were taken in the free space of the vault at the intervals shown after each of the procedures outlined in Table 2 were carried out, thus allowing the full concentration to build up. Some further observations were also made in a larger vacuum vault of 1200 cubic feet capacity, containing 20 bales of Argentine broomcorn, weighing about 350 pounds each, and tests were made on the possibility of a toxic concentration of the gas building up in a closed space after routine ventilation of the bales had been carried out. After removal from the vault the bales were placed on an outside platform to aerate for 1 hour, and 88 of them were stacked in a closed room of 9000 cubic feet capacity, samples of the air in the room being taken after 18 hours. The room was not ventilated in any way but the methyl bromide would be able to diffuse through cracks in the door and small cracks in a brick wall, the conditions being similar to what might be encountered in the average warehouse or storage space with doors and windows closed. After 18 hours a sample of 75 litres of air from the room failed to reveal any detectable concentration of methyl bromide. As this method is very sensitive, it is clear that no concentration of any toxicological significance was present in the room. This finding was confirmed by using a Halide Leak Detector, which is not accurately sensitive to concentrations below 35 parts per million, in all free parts of the room and again no positive reaction of methyl bromide was obtained.

It is apparent that, although gaseous methyl bromide is held somewhat tenaciously by bales of broomcorn as compared with other commodities such as fruits, vegetables and growing plants, at room or summer temperatures it will diffuse away well within 24 hours. This observation has been borne out in tests with the Detector under practical operating conditions, when it was found that bales at 50° to 60° F. fumigated with methyl bromide retained residues of 50 to 150 parts per million of the gas inside the bales for periods up to 6 hours after routine ventilation, and after 18 hours, concentrations below 35 parts per million were suggested by intermittent green colouration of the flame. It is therefore recommended that broomcorn treated with this fumigant be kept continuously ventilated while in cars or warehouses for at least 24 hours after treatment.

In comparing the degree of exposure of employees handling the fumigated goods with the situation as described by Watrous (10) it may be mentioned that in the case of the vacuum treatment, following routine "air washing" of the vault by the drawing of 2 successive vacuums of 2 inches of absolute mercurial pressure, only 5 to 10 minutes would be required for 1 or 2 men to remove the bales from the chamber. The bales, placed 3 at a time on wooden platforms, were rapidly wheeled out onto an outside

platform to await collection by the trucks of the importers. As no more than 3 or 4 treatments were carried out every 24 hours, the exposure to the vapours of the methyl bromide would not exceed 30 minutes per day, and of them only about 10 would actually be spent near the treated bales inside the confined space of the vault. Four employees engaged continuously for 5 months with the fumigation of broomcorn or other commodities suffered no illness or displayed any symptoms in any way resembling those described by Watrous or other authorities.

In the case of railroad cars fumigated with this compound, a period of 6 hours of continuous ventilation with both doors open has been required before persons are allowed to enter for unloading or other purposes.

ATMOSPHERIC FUMIGATION OF GREEN PEAS TO CONTROL LARVAE OF THE PEA MOTH, *Laspeyresia nigricana* Steph.

Growers of green peas on the Gaspé Coast, Province of Quebec, have in some seasons suffered considerable losses from infestations of the pea moth, *Laspeyresia nigricana* Steph. and hampers of fresh pods have sometimes been found, on arrival at the Montreal market, to have fairly large populations of pea moth larvae in them. These hampers are often shipped by express and are not placed on ice. At the request of the Division of Entomology, Science Service, some treatments were carried out on hampers shipped from New Carlisle, P.Q. The treatments are summarized in Table 3. All instars of the larvae were present in the pods, and good results were obtained despite the low degree of infestation. Observations on the peas, continued after fumigation, indicated that they were not harmed in any way, but that the subsequent development of moulds in the pods was not retarded as compared with the non-fumigated controls. Under practical conditions, it is suggested that a dose of 2 pounds of methyl bromide per 1000 cubic feet for 2 hours at normal summer temperatures in atmospheric vaults or air tight box or refrigerator cars would be sufficient to control the larvae in shipments of peas, with some initial circulation of the fumigant by means of fans and adequate ventilation of the space after exposure.

TABLE 3.—ATMOSPHERIC FUMIGATION OF GREEN PEAS IN THE POD WITH METHYL BROMIDE*

Dose methyl bromide in pounds per 1000 cu. ft.	Temperature of pods in hamper		Number pods examined after treatment	Larvae of pea moth found in pods			Percentage mortality
	Before	After		A	D	T	
.5	78	78	879	18	4	22	18
.75	80	79	943	4	9	13	69
1.0	78	76	681	4	6	10	60
1.25	76	73	744	2	13	15	87
1.5	76	75	864	0	15	15	100
1.75	72	72	650	0	18	18	100
CONTROL, not fumigated			1189	23	0	23	0

* Various doses and constant exposure period of 2 hours. Each treatment with 1 bushel hamper placed in experimental vault of 30 cubic feet capacity. Vault temperature 70° F. Fan circulation during exposure—10 minutes on, 20 minutes off. Hampers shipped by express from New Carlisle, P.Q., September 1st, 1941. Fumigation, Montreal, September 5th and 6th, 1941.

TESTS FOR GERMINATION AND BROMIDE RESIDUES IN DRIED PEAS FUMIGATED WITH METHYL BROMIDE

At the request of pea growers in British Columbia, analytical work was done to determine the amount of non-volatile bromide residue in dried peas and the germination following fumigation with methyl bromide. The peas were of the 1940 crop from British Columbia and were fumigated in Montreal in March, 1941. These peas were not infested and there was thus no opportunity to test the toxicity of the compound against pea weevils, but the treatments applied in Table 4 are those usually recommended for the control of these insects in peas.

TABLE 4. FUMIGATION OF DRIED PEAS WITH METHYL BROMIDE

No.	Treatment	Dose methyl bromide per 1000 cubic feet	Time	Residues		Germination
				Time of analysis after fumigation	Bromine in parts per million	
			hours	weeks		%
1	Vacuum sustained at 2″ abs. pressure	2.5	2	1	29.8	100
2	Atmospheric	2	16	2	24.0	98
3	Atmospheric	1.5	16	2	20.3	—
4	Untreated peas	—	—	—	2·8	100

Germination

Two weeks after fumigation, 50 peas from each treatment were placed on moist filter paper in a petri dish and left in the dark for 7 days. At the end of this time the peas which had sprouted and were in healthy condition were counted as germinated and their percentage of the total taken as the percentage germinated as shown in Table 4. The germination was not impaired in any way by the fumigation.

Bromide Residues

The technique adopted for determining the bromide residues was again one proposed by Dr. H. C. Dudley of the National Institute of Health, Washington, D.C. It is based on the principle of the liberation of iodine by bromine and is conducted in the following manner:

(1) In case any methyl bromide was present in the ground sample, it was hydrolyzed with a 1% solution of alcoholic potassium hydroxide and allowed to stand overnight. In the present instance, however, owing to the interval of time between treatment and analysis, it is doubtful if much methyl bromide would be present. Most of the bromide present would probably result from the formation of inorganic bromide salt or organic bromide compounds in the peas during the fumigation. (2) The sample was ashed several times, each ashing being followed by an extraction with

hot water. (3) The combined extracts were evaporated to dryness, and the dry residue was treated with a solution of sulphuric acid and poured into a bubbler. A solution of chromic-sulphuric acid was then added to the mixture. (4) The bromine given off was then bubbled through a solution of potassium iodide by drawing a low vacuum on the apparatus. The bromine liberated the iodine and the solution was titrated immediately with sodium thiosulphate N/100.

The samples were taken in the usual state and no corrections were made for the moisture content. A few lots of peas were subjected to vacuum sustained and atmospheric treatments at different dosages. The results are given in the following table.

The residues obtained can be compared with those recorded by Dudley *et al.* (3) from other vegetables fumigated with methyl bromide for 24 hours with a dosage of 2 pounds per 1000 cubic feet, viz.: white potatoes 12.9 parts per million, green beans 42 p.p.m., tomatoes 11 p.p.m., carrots 12.3 p.p.m., beets 38.3 p.p.m., turnips 20.9 p.p.m.

For some time there was doubt as to the exact nature of the bromide residue remaining in the foodstuffs fumigated with methyl bromide, but recent work by Shrader *et al.* (9) has brought out strong evidence to show that the bromine entering into combination with foodstuffs leads to the formation of inorganic bromides, and that there is no danger of any retention of the methyl bromide itself after adequate aeration and a lapse of a few days, while most of it disappears within 24 hours. There is justification therefore, for comparing the residues obtained in food fumigation with methyl bromide with observations on the effect of doses of bromide salts given to human beings and animals.

A study by Flinn (5) describes experiments in which a volunteer group of 70 adults taking 3 doses of sodium bromide were divided into two groups, one taking a total of 30 grains, the other a total of 45 grains per day for a period of 4 months. According to this author the subjects suffered no significant effects from the daily doses, other than an increase in the blood bromide in some individuals which was maintained at a more or less constant level during the treatment and then fell off rapidly as soon as the treatment ceased. This worker states that the ingestion of 30 to 45 grains of sodium bromide daily for four months did not affect the blood picture or the nervous reactions of the subjects.

These findings are of some interest in assessing the significance of bromide residues in fumigated foods. In order to consume the equivalent of the amount of bromide in a daily dose of 45 grains of a bromide salt, a person would have to eat 110 pounds of fumigated peas. Fifteen pounds of fumigated peas would have to be taken to ingest even the lowest medicinal dose of .32 grams of a bromide, as listed by the British Pharmacopoeia.

SUMMARY

At atmospheric pressure and at temperatures above 60° F., doses of 1.5 to 2 pounds of methyl bromide per 1000 cubic feet for 16 to 18 hours were found to be effective against insects liable to be found in imported broomcorn. This treatment could be applied in air-tight refrigerator or

steel box cars. In the vacuum treatment complete mortality of all insects liable to be found in the bales can be attained with a dose of 2.5 pounds of methyl bromide per 1000 cubic feet in a sustained vacuum of not more than 2 inches of absolute mercurial pressure for a period of 2.5 hours, with vault and bale temperatures of not less than 75° and 60° F. respectively. There is considered to be no hazard to persons handling the fumigated bales as long as normal air-washing routine is followed and continuous ventilation is provided for 24 hours after they are placed in storage.

The same fumigant can be used to kill larvae of the pea moth *Laspeyresia nigricana* Steph. in green peas when applied at the rate of 2 pounds per 1000 cubic feet for 2 hours at normal summer temperatures.

Dried peas suffered no loss of germinative power following standard vacuum and atmospheric fumigations with methyl bromide. Non-volatile bromide residues found in the peas after fumigation would not provide any consumer hazard.

ACKNOWLEDGMENT

The writers wish to acknowledge the valuable assistance of Miss A. Gaudet, Seed Analyst of the Plant Products Division, Dominion Department of Agriculture, Montreal, P.Q., loaned to this laboratory as a seasonal assistant, who helped in collecting much of the data on which this study is based.

REFERENCES

1. Bliss, C. I. The calculation of the dosage mortality curve. Ann. App. Biol. 22 : 134-167. 1935.
2. Bliss, C. I. The toxicity of poisons applied jointly. Ann. App. Biol. 26 : 585-615. 1939.
3. Dudley, H. C., J. W. Miller, P. A. Neal, and R. R. Sayers. Studies on foodstuffs fumigated with methyl bromide. U.S. Pub. Health Repts. 55 : 2251-2282. 1940.
4. Fisher, R. A. and F. Yates. Statistical tables for biological, agricultural and medical research. Pp. 5-8, Oliver and Boyd. London. 1938.
5. Flinn, F. B. The appearance of blood bromide after oral ingestion. Journ. Lab. and Clin. Med. 26 : 1325-1329. 1941.
6. "Grain". Coroner's report on fumigant death. P. 12. Nov. 1941.
7. McLaine, L. S. and H. A. U. Monro. Hydrocyanic acid gas in the vacuum fumigation of broomcorn under winter conditions. Journ. Econ. Ent. 32 : 94-98. 1939.
8. Monro, H. A. U. and R. Delisle. Fumigation of wet cotton with methyl bromide. Sci. Agr. 21 : 584-587. 1941.
9. Shrader, S. A., A. W. Beshgetoor, and V. A. Stenger. Determination of total and inorganic bromide in foods fumigated with methyl bromide. Ind. Eng. Chem. 14 : 1-4. 1942.
10. Watrous, R. M. Methyl bromide, local and mild systemic toxic effects. Ind. Med. 2 : 575-579. 1942.

STUDIES ON BLACKROOT OF SUGAR BEET SEEDLINGS[1]

A. A. Hildebrand and L. W. Koch[2]
Dominion Laboratory of Plant Pathology, Harrow, Ont.

[Received for publication March 24, 1943]

In Ontario, as in many other regions where sugar beets are grown, blackroot almost every year threatens to cause or actually does cause serious reduction in stand of seedlings. In a series of experiments carried out in the greenhouse during the past 2 years, the incidence and severity of blackroot were studied in relation to aeration of the soil by cultivation, row application of commercial fertilizer, seed treatment with certain fungicidal dusts, and incorporation of green manure in the form of a cover crop. The effects of these various treatments on germination were also noted. Other studies centred around an attempt to answer in part at least the controversial question, "Do seedlings affected with blackroot recover and if so how do they compare in later usefulness with non-infected seedlings?" The findings in connection with the investigations carried out along the lines indicated above are reported in the present paper.

MATERIAL AND METHODS

A. *Soil*

In May 1491, when blackroot was at its worst, soil was stripped from rows in a number of fields in different localities where incidence of disease was highest. Although all samples consisted of essentially the same type of soil, a Brookston clay loam, nevertheless, before being used in any experiment, the various collections were thoroughly mixed.

B. *Seed*

The seed was furnished by the Canada and Dominion Sugar Company, Chatham, Ontario, and formed part of a lot which, produced in Ontario in 1941, possessed high germinability. The seed, standardized as to size (16/64 to 14/64 inch) by careful screening, was planted at a depth of $\frac{1}{2}$ inch in greenhouse flats. In each flat were planted 176 seeds arranged in 4 rows, 44 seeds per row, the seeds being spaced $\frac{1}{2}$ inch apart in the rows.

C. *Fertilizer*

To the soil of certain flats was added a 2–16–10 commercial fertilizer at the rate of 400 lb. per acre, half of which amount was placed in a band in contact with the seed, the other half in a band $1\frac{1}{2}$ inches below and a little to one side of the seed.

SOIL AERATION AND FERTILIZER EXPERIMENTS

In the literature it is implied in some instances (7) and stated quite directly in others (9, 14) that cultivation of the soil as soon as the drill rows can be followed lessens or helps to avoid damage by blackroot. Since

[1] Contribution number 735, Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Assistant Plant Pathologist, and Pathologist-in-Charge, respectively.

this disease is caused by one or more of several different fungi which are inhabitants of the soil and which cannot be removed therefrom by cultivation, it seems doubtful that this practice could have as salutary effects as are or have been claimed for it. In theory, at least, it seems possible that an already serious situation instead of being improved might rather be aggravated not only by too early disturbance of the soil around the roots of the young seedlings but also by the spread of inoculum from infected to non-infected areas.

It is frequently stated (3, 4) that few crops respond more profitably to proper fertilization than do sugar beets. The response is reflected not only in increased yield and sugar content but also in reduction in incidence of blackroot (3, 4, 1, 2) and other diseases (13). Involved in the question of what constitutes proper fertilization are a number of factors including the fertilizer analysis that will give best results, the amount to be applied, the time of application, and of especial importance, the placement of the fertilizer. On the basis of experiments carried out both in England and in the United States, Lewis (15) has recently evaluated the relative merits of broadcasting fertilizers as compared with their restricted application in a zone near the seed and, as regards root crops including sugar beets, reports as follows: "The results presented confirm American experience that higher crop yields are obtained by applying fertilizers in restricted zones or bands than by broadcasting and that no one method of restricted application is universally the best." Coons, Kotila and Bochstahler (8) reported in 1941 that very promising results had been obtained in the control of Aphanomyces spp. which are exceedingly important in causing damping-off of seedlings, by the use of adequate amounts of phosphate fertilizer with the seed.

With the above considerations in mind as to the possibilities of both cultivation and fertilizer application, a series of three experiments was carried out. The first two, of an exploratory nature, were on too small a scale to permit statistical analysis of results. These results were definite enough, however, and were in accordance with those obtained in a third, large-scale experiment, details in connection with which are as follows. Twenty-four flats were planted as described above. In 12 of them fertilizer was added. At the first appearance of blackroot, which occurred about the seventh or eighth day after planting, the soil in 12 of the flats, 6 with fertilizer and 6 without, was cultivated, using an ordinary table fork the tynes of which had been bent down to form a small cultivator. At 4-day intervals up to the thirty-second day of planting (by which time there was stabilization both as to germination of seeds and mortality of seedlings) the soil was cultivated a total of 7 times. Every day during the course of the experiment, the seedlings were counted and records taken as to the number of seeds germinating and the number of seedlings dying. The data obtained from the four different treatments, each replicated 6 times, were analysed by using the analysis-of-variance methods, with results as shown in Table 1.

Referring to Table 1, it will be noted that germination was poorest in cultivated soil to which no fertilizer had been added and highest in cultivated soil to which fertilizer had been added. In regard to blackroot the disease was significantly greater in cultivated than in non-cultivated soil

TABLE 1.—EFFECT OF CULTIVATION AND APPLICATION OF FERTILIZER ON GERMINATION AND INCIDENCE OF BLACKROOT IN SUGAR BEETS

	Germination		Incidence of blackroot	
	No cultivation	Cultivation	No cultivation	Cultivation
	%	%	%	%
No fertilizer	181.0	145.3	78.9	87.7
Fertilizer	197.0	216.3	70.7	82.3
	Mean difference of 25.3% required for significance		Mean difference of 9.95% required for significance	

whether or not fertilizer had been added. Thus, it would appear that any increase in germination resulting from cultivation would be counteracted by higher mortality of seedlings as the result of the same practice.

SEED TREATMENT EXPERIMENTS

An immense amount of work has been done in attempts to control blackroot by seed treatment and it is far beyond the scope of the present paper to attempt to review the literature in that connection. It is interesting to note, however, that investigators in different localities using the same seed disinfectants have had widely varying results. On the one hand, for example, in 1939 Campbell (5) reported that none of a large number of treatments (including the use of Ceresan and New Improved Ceresan) used during 2 years of investigation gave any significant control of blackroot when the soil was heavily infected. Later, in 1940, Campbell (6) reported that seed treatment with 2% Ceresan had consistently resulted in degrees of control of *only* the early pre-emergent stage of blackroot but sufficient to give up to 25% increase in unthinned stands. Afanasiev and Morris (2) recently reported that seed treatment with Ceresan and New Improved Ceresan had but slight effect on the seedling diseases, on the stand, or on the yield of sugar beets as compared with the check. On the other hand, in 1937 LeClerg (14) reported that in certain areas of Minnesota, the use of 2% Ceresan gave good results. In 1939, Leach and Houston (12) stated that "large-scale experiments in Central California indicate that damping-off of sugar beets can be controlled by seed treatment with Ceresan or red oxide of copper." Whether it be Ceresan, New Improved Ceresan or any one of many possible seed disinfectants that might be used, differences in results such as those indicated above are only to be expected when it is recalled how variable are soil types and conditions, degrees of soil and seed infestation and other important factors in different localities.

Since blackroot is caused by fungi which for the most part are residual in the soil, the best that can be hoped from any seed treatment is, it would seem, that it will destroy certain seed-borne pathogens such as Phoma and Cercospora, and for a limited period following germination, afford some measure of protection to the young seedlings. It was with expectations no greater than those that tests were carried out using 2% Ceresan (ethyl

mercury chloride), Nomersan or Thiosan (50% tetra-methyl thiuram disulphide) and Spergon (tetrachloro-para-benzoquinone), according to the manufacturers' directions. Nomersan and Spergon, two of the more recently produced seed disinfectants, have the advantage in being less dangerous to use than the highly poisonous Ceresan. The results of the tests which were replicated 3 times and which are based on counts taken 28 days after planting of the treated seed are presented in Table 2.

Referring to Table 2 it will be noted that treatment of seed with Ceresan and Nomersan resulted in much higher germination than in the case of non-treated seed. The increase in germination of the Ceresan- and Nomersan-treated seeds over that of the non-treated seeds can be regarded as a measure of the effectiveness of these two fungicidal dusts in providing protection against damping-off in its pre-emergent phase. As far as the post-emergent phase is concerned none of the treatments provided adequate protection. On a comparative basis, treatment with Nomersan and Ceresan gave best results but, actually, treatment with these two chemicals resulted finally in only about 30% stand of healthy seedlings. The fact should not be minimized, however, that seed treatment with Nomersan and Ceresan resulted in about 10% greater stand of healthy seedlings than in the case of no treatment at all.

TABLE 2.—EFFECT OF SEED TREATMENT ON GERMINATION AND INCIDENCE OF BLACKROOT IN SUGAR BEETS

Treatment	Seeds planted	Germination		Health seedlings	Disease incidence		
					Affected	Dead	Total
	no.	no.	%	%	%	%	%
Ceresan	528	946	179.1*	30.8	6.2	62.8	69.0
Nomersan	528	999	189.2	31.1	10.6	58.3	68.9
Spergon	528	607	114.9	17.6	3.6	78.7	82.3
Check	528	587	111.1	21.6	4.9	73.4	78.3

* The figures in this column were arrived at in each case by expressing the total number of seedlings which appeared above-ground as a percentage of the number of seeds planted.

COVER-CROP EXPERIMENTS

In the case of rootrot diseases of a number of economic plants, as, for example, cotton root rot, strawberry root rot and damping-off of tomato seedlings, it has been shown by King (11), by Hildebrand and West (10), and by L. T. Richardson (17), respectively, that incidence and severity of these several diseases can be modified by certain green-manurial treatments. The studies of Hildebrand and West (10) clearly demonstrated that populations of organisms including representatives of certain groups of fungi, nematodes and bacteria, which had become established in a certain soil and which, as a result, had rendered that soil inimical to the healthy growth of varieties of the cultivated strawberry, were amenable to change. Of especial interest was the fact that the new microbiological equilibria which became established in soybean-treated rootrot soil exerted

a markedly beneficial effect on a subsequent planting of strawberries. In this connection it is interesting to refer to the recent work of J. K. Richardson (16) who found that corn following soybeans in corn root rot soil developed perfectly healthy roots in which it was difficult to find even a trace of decay.

With the above considerations in mind, a series of experiments was carried out in which sugar beet seeds were planted in root rot soil with which certain cover crops including soybeans, corn, and alfalfa, had been incorporated and which, for comparison, was treated in other ways. Results based on counts of seedlings taken 28 days after planting the seed are presented in Table 3.

TABLE 3.—EFFECT OF GREEN-MANURIAL AND OTHER TREATMENTS OF ROOTROT SOIL ON GERMINATION, INCIDENCE OF BLACKROOT AND VIGOUR OF SEEDLINGS

Treatment	Seeds planted	Germination		Condition of seedlings		Weight of 150 seedlings
				Healthy	Dead or Diseased	
	no.	no.	%	%	%	gm.
Corn	555	1152	207*	92.4	7.6	114
Soybean	555	1068	192	89.6	10.4	315
Steam	450	1053	234	83.1	16.9	130
Alfalfa	555	960	173	67.5	32.5	—
2–16–10	450	279	62	47.3	52.7	—
Check	450	369	82	20.3	79.7	—

* The figures in this column were arrived at in each case by expressing the total number of seedlings which appeared as a percentqge of the number of seeds planted.

Referring to Table 3 it will be noted that germination was highest in steamed soil and very good in both corn- and soybean-treated soils. Following alfalfa, germination was not so good and was very poor in untreated soil and in that to which commercial fertilizer had been added. Incidence of blackroot was lowest in soils with which corn and soybeans had been incorporated. Although there was slightly higher incidence of disease among seedlings in the soybean-treated soil than among those following corn, nevertheless, the vigour of seedlings in the soybean series was markedly greater than in any other series, including corn. The superiority of the seedlings in the soybean-treated soil, over those in soils receiving other treatments is clearly shown in Figure 1, A. As further reference to Table 3 will show, the weight of 150 sugar beet seedlings grown in the soybean-treated soil was almost 3 times that of a similar number of seedlings grown in the corn-treated and in the steamed soil. Only about 20% of the seedlings which developed in the untreated soil survived in a healthy condition.

SURVIVAL OF BLACKROOT-INFECTED SEEDLINGS

During the course of the experiments described above, over 30,000 seedlings were kept under close observation over considerable periods of time. In general, it was noted that in a greenhouse maintained at temperatures ranging from 17–19° C., seeds planted in root-rot soils which

FIGURE 1. A. Six-weeks-old sugar beet seedlings growing in naturally infected soil treated prior to planting with (1) dextrose, (2) cover crop of corn, (3) cover crop of soybeans and (4) steam. B. Six-weeks-old blackroot-infected sugar beet seedling. C. and D. The same seedling as in B showing progress in recovery from the disease after 1- and 2-month intervals, respectively.

varied in type from marl to clay loam and to which moderate quantities of water were added as required, started to germinate on either the fourth or fifth day after planting. Greatest germination usually took place from the sixth to the ninth days, inclusive, the peak being reached on the seventh and eighth days. Blackroot usually made its first appearance on the seventh or eighth day after planting, just when germination was at its height, and mortality of seedlings was greatest from the ninth to the thirteenth day, reaching a peak on the tenth and eleventh days. With surprise it was noted that of the seedlings which became infected after the initial period of high mortality (ninth to thirteenth day), a relatively high proportion did not die and under the conditions of the experiment showed remarkable power of recovery. This circumstance suggested implications of considerable practical importance. It was decided, therefore, to investigate the matter further.

In February 1942, 125 healthy and 125 carefully selected, blackroot-infected seedlings, were transplanted from root-rot soil in flats to greenhouse compost soil in 5-inch pots. The blackroot plants were all so severely affected that the hypocotyl in each case was reduced to a thin black thread (Figure 1, B) and was no longer able to support the plant in an upright position. The healthy and diseased plants remained in the greenhouse for 2 months and during that period none of the latter died. The diseased plants, on the contrary, slowly but surely recovered, the progress of their recovery being as shown in Figure 1, B, C, and D. New adventitious roots appeared on the diseased hypocotyls which, meanwhile, gradually filled out and became strong enough to support the young plants in an upright position. On April 22, healthy and formerly diseased plants were planted in an outdoor plot at 1-foot intervals in rows spaced 22 inches apart. The plants were harvested October 19, 1942. Data in connection with the experiment are summarized in Table 4.

TABLE 4.—COMPARATIVE YIELDS OF BEETS DEVELOPING FROM INITIALLY-HEALTHY AND DISEASED SEEDLINGS

Type of seedling	Beets harvested	Gross weight	Average weight	Range in weight	Approximate yield per acre
	no.	lb.	lb.	lb.	tons
Healthy	95*	447.2	4.7†	2.1 – 9.6	51‡
Blackroot	97	388.7	4.0	1.3 – 7.6	43

* A few of the 125 beets originally planted were used for experimental purposes, several were "boulters" and a few became infected with Savoy, correction for all of which was made in calculating yield.

† The average weight of commercial beets is about 1.5 lbs.

‡ This estimate based on rows 22 inches apart, thus 23,760 feet of beet-rows per acre, in which beets are spaced 12 inches apart.

As reference to Table 4 will show, seedlings initially infected with blackroot developed into mature beets which averaged 4 pounds in weight, ranged in weight from 1.3 to 7.6 pounds and yielded at the rate of approximately 43 tons per acre. This yield is only about 15% less than that resulting from the initially-healthy seedlings. The results show that under ideal conditions blackroot seedlings not only recover but are capable of producing beets of commercial value.

DISCUSSION

It is realized that conditions which obtain in a greenhouse may differ widely from those encountered out-of-doors. It seems safe to assume, however, that results obtained in the former environment will, *in general*, be similar to, though probably less pronounced than those encountered in actual field practice. In fact, there is strong supporting evidence for this assumption in so far, at least, as certain of the results observed in the greenhouse are concerned. It was pointed out above that when sugar beet seeds were planted in root-rot soil in the greenhouse, there was a period beginning about the ninth day after planting and extending until the thirteenth, during which mortality of seedlings was highest. After that initial period of high mortality, fewer seedlings became infected and a much smaller proportion of those that did become infected, died. A similar sequence has frequently been observed in the field though the time relationships have not as yet been so carefully determined. Growers often refer to a field as "coming out of blackroot." It can readily be understood how a misconception might arise in regard to the efficacy of cultivation in reducing blackroot. If a field of beets were cultivated during the 3- to 4-day period when seedling mortality was highest and then a day or two later infection dropped sharply, it might be inferred that cultivation had brought about the improvement. The truth of the matter probably is, however, that reduction in mortality would have taken place in any case. The results of the greenhouse experiments in this connection showed clearly that when the soil was cultivated at 4-day intervals commencing at the first appearance of blackroot, incidence of disease was significantly higher than when the soil was not disturbed. It should be emphasized that the writers are not advocating discontinuance of early cultivation. When weather conditions are such that a crust forms on the surface of the soil and the young seedlings cannot break through or, if they have broken through, and their roots are suspended in an air-pocket beneath the crust, then, fields so affected must be rolled and cultivated to save the stand. Apart from this condition, however, and in the case of fields infected with blackroot, it would seem that the best time to cultivate would be just after the period of initial high mortality. Cultivation at that time would not only destroy weeds but would also bank the loosened soil more closely around the seedlings, thereby affording additional protection against whipping by the wind as well as encouraging more rapid development of adventitious roots. Until further investigations in this connection have been carried out in the field, it may be asserted that while early cultivation is not to be discouraged, nevertheless, too much emphasis is not to be placed on it as a cure or preventive of blackroot.

As will already have been noted from the text, the fertilizer experiments carried out in the present studies were of the simplest type. They sufficed, however, to furnish information on the question in point, namely, the effect, beneficial or otherwise, of row application of fertilizer on germination and incidence of blackroot. The results which show clearly that placement of fertilizer in a restricted zone near the seed not only increased germination but also reduced incidence of blackroot, confirm those obtained by workers elsewhere.

In regard to the seed-treatment experiments, the results were almost as expected. Ceresan and Nomersan afforded the seedlings a considerable measure of protection against the pre-emergent phase of damping-off but failed to protect them sufficiently during the post-emergent phase to ensure a profitable stand. The fact, however, that seed-treatment with Nomersan and Ceresan resulted in a 10% greater stand of healthy seedlings than in the case of no treatment at all would lend support to the recommendation that where blackroot is likely to be a factor, treatment of seed with one or other of these two fungicidal dusts should be encouraged but with reservation of claims as to their effectiveness in preventing the disease.

In the various experiments described above, no results were more interesting or, perhaps, more potentially important from the practical standpoint, than those encountered following the treatment of root-rot soil with green manure in the form of cover crops. When, for example, corn was incorporated with the soil, germination was of the order of 207 as compared with only 82 in the case of untreated soil. Soybean-treated soil also gave the high relative germination of 192. But even more striking was the effect of these two cover crops in reducing blackroot. Disease incidence after corn, after soybeans and in steamed soil was 7.6, 10.4, and 16.9%, respectively. That is, less disease occurred after corn and soybeans than in lots of the same root-rot soil sterilized with steam. Although slightly less disease occurred after corn than after soybeans, nevertheless, so far as vigour of growth is concerned, the seedlings in the soybean-treated soil were far superior to those in the corn-treated or steamed soil. Thus, primary interest in the experiment centres on soybeans and in their apparent remarkable capacity for correcting and otherwise improving a naturally-infected root-rot soil. Time did not permit chemical analysis of these variously treated soils or microbiological examination of the roots of the sugar beet seedlings grown in them so that at the moment evidence is lacking to account for the differences observed. This much is known that a single cover crop of soybeans greatly improved the tilth of the soil. The point of interest is whether or not the results obtained in the greenhouse can be duplicated in field practice. Experiments to determine this point are now being planned.

Every year in Ontario a greater or lesser number of growers are confronted with the problem of having to decide whether stands of sugar beet seedlings infected with blackroot are worth while keeping. If the results obtained in the greenhouse experiments described above in connection with survival of infected seedlings can be regarded even as partially indicative of what may take place in the field, this much at least can be offered by way of recommendation. Decision as to whether or not to discard an infected stand should be delayed until after the period of high initial mortality. Even then before a final decision is made it should be remembered that if conditions are at all favourable, probably an appreciable percentage of infected seedlings will recover. In the greenhouse experiment, practically all of the originally-infected seedlings not only recovered but proved capable of producing beets of commercial value.

SUMMARY

The following results were obtained in a series of experiments carried out under greenhouse conditions, in which sugar beet seeds, treated or untreated, and standardized as to size (16/64 to 14/64 inch), were planted in blackroot-infested soil (a Brookston clay loam), subjected to various treatments including cultivation, row-application of commercial fertilizer (2–16–10) and incorporation of green manure in the form of a cover crop.

(a) General Observations

At temperatures ranging from 17–19° C., seeds planted in soil to which moderate quantities of water were added as required, started to germinate on either the fourth or fifth day after planting. Greatest germination usually took place from the sixth to the ninth days, inclusive. Blackroot usually made its first appearance on the seventh or eighth day after planting and mortality of seedlings was greatest from the ninth to thirteenth day. Of the seedlings which became infected after the initial period of high mortality, a relatively high proportion did not die and under the conditions of the experiment showed remarkable power of recovery.

(b) Detailed Results

Blackroot of seedlings was significantly greater in soil that was cultivated than in the same soil left undisturbed, regardless of whether or not fertilizer was added.

Germination was poorest in soil that was cultivated and to which no fertilizer was added, and highest in cultivated soil to which fertilizer was added.

Blackroot was less prevalent in root-rot soil when a 2–16–10 commercial fertilizer was applied by row application at the rate of 400 pounds per acre, half of which amount was placed in a band in contact with the seed, the other half in a band $1\frac{1}{2}$ inch below and a little to one side of the seed, than when no fertilizer was added, regardless of whether or not the soil was cultivated.

Treatment of seed with Ceresan and Nomersan resulted in much higher germination than in the case of non-treated seed. While these two chemicals afforded the seedlings a considerable measure of protection against the pre-emergent phase of damping-off, they failed to protect them sufficiently during the post-emergent phase to ensure a profitable stand.

Incidence of blackroot was lower in root-rot soil with which cover crops either of corn or of soybeans had been incorporated as green manure than in lots of the same soil sterilized with steam. The vigour of seedlings in the soybean-treated soil was markedly greater than in any other series including corn.

Blackroot-infected seedlings when grown for 2 months in the greenhouse and then transferred to an outdoor plot, all recovered and developed into mature beets which, in the aggregate, gave a yield only 15% less than that resulting from the use of initially-healthy seedlings.

REFERENCES

1. AFANASIEV, A. A. and H. E. MORRIS. Greenhouse experiments for control of seedling diseases of sugar beets. Phytopath, 30 : 784-785. 1940.
2. AFANASIEV, A. A. and H. E. MORRIS. Control of seedling diseases of sugar beets in Montana. Phytopath. 32 : 477-486. 1942.
3. ANONYMOUS. Sugar beets in Michigan. Mich. Agr. Expt. Sta., Cir. Bul. 175. 1940.
4. ANONYMOUS. Increase yield and improve quality of sugar beets. The Fertilizer Review, 17 : 10. 1942.
5. CAMPBELL, L. Blackroot of sugar beets in the Puget Sound section of Washington. Wash. Agr. Expt. Sta., Bul. 379. 1939.
6. CAMPBELL, L. The strip method of soil treatment for the control of blackroot of sugar beets. Phytopath. 30 : 785. 1940.
7. COONS, G. H. The root diseases of the sugar beet. Sugar Beet Institute. 3rd. Ann. Meeting, 28-34. 1924.
8. COONS, G. H., J. E. KOTILA and H. W. BOCHSTAHLER. Blackroot investigations in Michigan and Ohio. Proc. Am. Soc. Sugar Beet Technologists, Eastern United States and Canada, 2nd. Regional Meeting, 35. 1941.
9. EDSON, H. A. Seedling diseases of sugar beets and their relation to rootrot and crown-rot. Jour. Agr. Res. 4 : 135-168. 1915.
10. HILDEBRAND, A. A. and P. M. WEST. Strawberry rootrot in relation to microbiological changes induced in rootrot soil by the incorporation of certain cover crops. Can. J. Research, C, 19 : 183-198. 1941.
11. KING, C. J. A method for the control of cotton rootrot in the irrigated southwest. U.S. Dept. Agr. Cir. 425. 1937.
12. LEACH, L. D. and B. R. HOUSTON. Influence of moisture and other factors on the efficiency and safety of sugar beet seed treatment. Phytopath. 29 : 15. 1939 (Abstract).
13. LEACH, L. D. and A. E. DAVEY. Reducing southern sclerotium rot of sugar beets with nitrogenous fertilizer. Jour. Agr. Res. 64 : 1-18. 1942.
14. LECLERG, E. L. Treatment of sugar-beet seed increases stand and yield. Minn. Agr. Extension Division Cir. 57. 1937.
15. LEWIS, A. H. The placement of fertilizer. I. Root crops. Jour. Agr. Sci. 31 : 295-307. 1941.
16. RICHARDSON, J. K. Studies on rootrot of corn in Ontario. Can. Jour Research, C, 20 : 241-256. 1942.
17. RICHARDSON, L. T. A Phytophthora tomato disease new to Ontario. Can. Jour. Research, C, 19 : 446-483. 1941.